APPENDIX 2

CARLISLE REDUNDANT WELL - WELL CONSTRUCTION & TESTING REPORT

871 Equestrian Court, Unit 1, Oakville ON L6L 6L7
Tel: 647-795-8153 | www.pecg.ca

Carlisle Redundant Well (FDC03RR)

Well Construction and Testing

Palmer Project #
2108704

Prepared For
R.V. Anderson Associates Limited

June 5, 2024

871 Equestrian Court, Unit 1, Oakville ON L6L 6L7
Tel: 647-795-8153 | www.pecg.ca

June 5, 2024

Andrew McGregor
Senior Planner / Project Manager, EA & Approvals
R.V. Anderson Associates Limited
43 Church Street, Suite 104, St. Catharines ON L2R 7E1

Dear Andrew:

Re:
Carlisle Redundant Well
(FDC03RR)
Project #: 2108704

Palmer is pleased to submit the attached report summarising the results of well construction, aquifer assessment, GUDI assessment and groundwater quality assessment for the newly constructed Redundant Well FDC03RR located at 84 Acredale Drive, Carlisle, Hamilton, ON.

Thank you for the opportunity to be of service on this project. We trust that this report will be satisfactory for your current needs. If you have any questions or require further information, please contact our office at your convenience.

This report is subject to the Statement of Limitations provided at the end of this report.

Yours truly,

Jason Cole, M.Sc., P.Geo.
VP, Principal Hydrogeologist

Executive Summary

Carlisle Well FDC03RR was constructed to provide a redundant source of water for the community of Carlisle. It is expected that FDC03RR will be used as a backup well of the existing water supply well FDC03R. The well was constructed in accordance with Ontario Regulation (O. Reg.) 903 and its associated provincial manual, Water Supply Wells – Requirements and Best Management Practices.

A step-drawdown test and a 72-hour pumping test were completed for FDC03RR in general accordance with O. Reg 903, the Practical Guidelines for Test Pumping in Water Wells (ICRC) and the Guide to Conducting Well Pumping Test (BC). Our well and aquifer assessment based on the data recorded from the step-drawdown test and 72-hour pumping test conclude that:

- Specific well capacity ranges from 14.5 to 21.4 m^3/hr/m (348 to 513.6 m^3/day/m);
- Well loss analysis and well efficiency analysis show the constructed well is efficient;
- The aquifer is a confined aquifer with weak leakage from overlying overburden;
- No hydraulic boundary was encountered during 72-hour pumping test;
- Transmissivity (average T value) of the aquifer is 895 m^2/day (0.01035 m^2/s);
- Storativity (average S value) of the aquifer is 0.00095;
- Sustainable yield estimates range from 29 to 69 L/s, averaged at 49 L/s; and
- No aquifer mining was observed during pumping test.

A comprehensive sampling program, proposed by the City of Hamilton, was undertaken and included testing for the assessment of raw groundwater drinking quality and Groundwater Under Direct Influence (GUDI) level conditions. Samples were taken from both FDC03RR and observation wells multiple times to assess spatial variation of water quality as well as quality fluctuation over time. Sampling was conducted in general accordance with the guidelines of Practices for the Collection and Handling of Drinking Water Samples of Ontario (2009) and Palmer's groundwater sample protocols. Analysis testing was completed by the City of Hamilton's accredited environmental labs. Based on the testing results, it is concluded that:

- The groundwater from FDC03RR does not have a significant surface water source, and groundwater quality has not been significantly impacted by contamination associated with surface water; and

- The raw groundwater from FDC03RR meets Ontario Drinking Water Standards (ODWQS) standards except that it exceeds the reporting criteria of sodium.

Based on construction records, the well and aquifer performance assessment and the comprehensive groundwater quality assessment, it is concluded that the FDC03RR is suitable to be used as a redundant production well.

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Photo Album 1. Well Construction
Photo Album 2. Pumping Test and Erosion Surveillance
Locating Tickets (Ontario One Call and Agents)

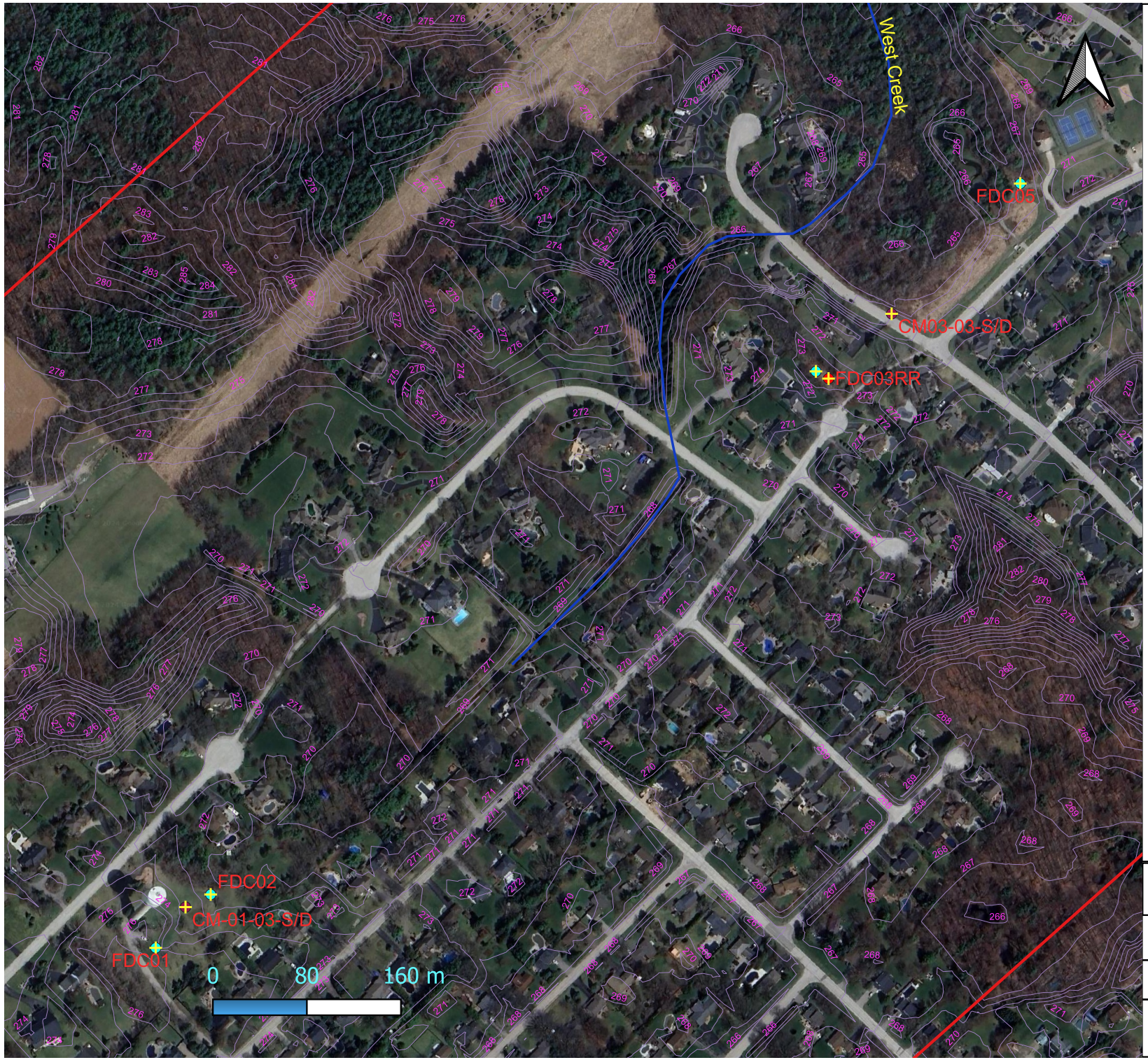
1. Introduction

Palmer was retained by R.V. Anderson Associates Limited (the “client”) to provide hydrogeological services for the City of Hamilton to construct and test a new water supply well FDC03RR. **Figure 1** shows the existing Carlisle Field and the location of FDC03RR. The water supply well will be used to provide a redundant source of water for the community of Carlisle and will be used as a backup well for the existing supply well (FDC03R) at the same site. The FDC03RR is located at 84 Acredale Drive, Carlisle, ON, the same site as FDC03R, and is approximately 14 m away from FDC03R.

The majority of Carlisle is serviced by municipal water supply through municipal wells, Carlisle Well Field, with the remainder being serviced by private wells. The municipal water supply system currently consists of four (4) production wells (FDC01, FDC02, FDC03R and FDC05), four sentry wells (CM-01-03-S/D and CM-03-03-S/D) and associated treatment, storage and distribution infrastructure. FDC03RR once approved and commissioned will become part of Carlisle Well Field.

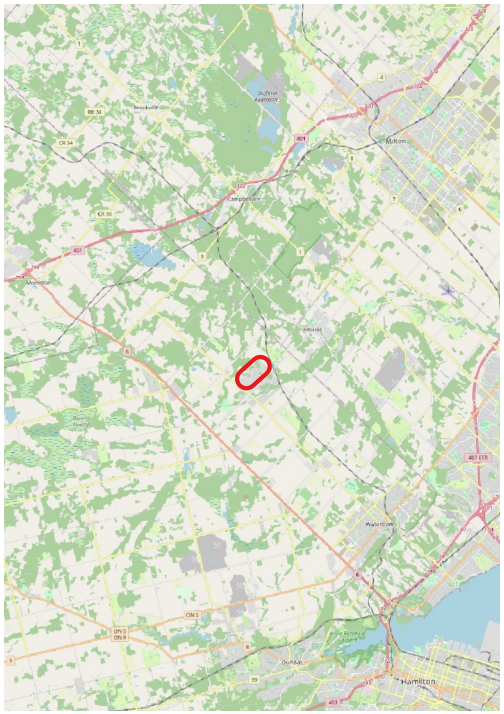
Based on the proposal, the scope of work included:

- Planning, design and health and safety for well drilling and pumping test;
- Environmental Activity and Sector Registry (EASR) with the Ontario Ministry of the Environment, Conservation and Parks (MECP) for pumping test;
- Tendering for well contractors;
- Supervision of well construction;
- Supervision of pumping test and groundwater level monitoring;
- Groundwater sampling and in-situ quality monitoring for water quality assessment and Groundwater Under Direct Influence (GUDI) assessment;
- Groundwater sampling for environmental isotope study; and
- Reporting.



LEGEND

- Carlisle Well Field
- Existing Wells
- Redundant Wells
- Sentry Wells
- Water Course
- Top Contour (1 m)



CLIENT
R.V. ANDERSON ASSOCIATES LIMITED

PROJECT
Carlisle Well Field, Hamilton, Ontario

TITLE
Carlisle Well Field and Redundant Well

Palmer™

REF. NO: 2108704

Figure 1

2. Well Construction

Hydrogeological services of Palmer for well construction included locating, tendering for contractor, construction supervision, cutting sampling and classification, and well log creation.

Palmer representatives attended a preliminary site meeting on April 6, 2022 with representatives from R.V. Anderson and the City of Hamilton. The purpose of the meeting was to discuss the well construction project and to select a suitable location for the well.

To obtain competitive bids for the well construction, Palmer solicited quotations from a number of water well drillers who operate business in Southern Ontario. Two quotations were obtained, and the client awarded the contract to Highland Water Well Drilling Inc.

Palmer obtained locates through Ontario One Call prior to the well contractor proceeding with any intrusive drilling activities.

The well construction was conducted in accordance with the requirements of O. Reg. 903 and its associated provincial manual, Water Supply Wells – Requirements and Best Management Practices.

2.1 Construction Procedure

Construction of FDC03RR was executed from April 17 to April 20, 2022 by Highland Water Well Drilling Inc. with Palmer's staff supervising and coordinating full time, on site, operation. The construction of FDC03RR was carried out in three steps, including well drilling, grouting and well development.

2.1.1 Well Drilling

Well drilling was conducted with a water well drilling rig (Driltech D25). Compressed air was used to bring cuttings to surface until a depth of 5.0 meters below ground surface (mbgs), and from this depth, a mixture of clean water and compressed air was used as drilling fluid. The well drilling can be broken into the following steps:

1. Rotatory drilling of a temporary casing and thicker drilling rods to bedrock top (15 mbgs). Both the temporary casing and drilling rod have a drilling bit at bottom;
2. Withdraw the thicker drilling rods;
3. Rotatory drilling of the permanent casing (with centralizers) and thinner drilling rods to sound bedrock (18 mbgs). Both the permanent casing and drilling rod have drilling bit at bottom. The lengths of permanent casing were connected with welding;
4. Rotatory drilling of the thinner drilling rods to target depth (33 mbgs) while the permanent casing sites on sound bedrock; and
5. Withdraw the thinner drilling rods.

Cutting samples were taken approximately every 1.5 meters to assess the soil and bedrock stratigraphy. A **Photo Album** provided as a separate document provides photos of the drilling activities.

2.1.2 Grouting

Grouting is a procedure of sealing the annular space between the permanent casing and the borehole wall, as well as sealing the porous space and fractures in the bedrock formations near the permanent casing with the grout. The ultimate purpose of grouting is to ensure that the surface water and contaminants will not flow into well through annular space between permanent casing and the borehole wall, and to create a sound well structure.

The grout for this project was made from mixing water and Portland cement in a ratio of 19 litres of water to 40 kg of cement. 40 bags of cement were used to prepare the grout. Grout was mixed in a grout pump and injected through tremie pipes of 4.0 cm outside diameter to the bottom of the permanent well casing. The grouting was executed in three stages:

a. Stage 1 grouting – tremie pipe inserted to the bottom of the annular space between the temporary casing and the permanent casing, and grout was injected to displace water from the bottom of the annular space until returning grout reached the same consistency as injected grout;
b. Stage 2 grouting – withdraw 9 m of temporary casing, tremie pipe was inserted to 9 mbgs in the annular space between the the temporary casing and the permanent casing and grout was injected until returning grout reached same consistency as injected grout; and
c. Stage 3 grouting – withdraw 6 m of temporary casing, tremie pipe inserted to 6 mbgs in the annular space between the permanent casing and borehole wall, and grout was injected until returning grout reached same consistency as injected grout.

After completion of grouting, more than 24 hours were given for the grout to set before conducting any work on the well. The consolidated grout settled to approximately 0.5 m below ground surface. The space caused by settling of grout was sealed with bentonite chips and topped with native soil.

It is noted that a concrete pad and pitless adapter may be installed at a later date, but were not installed as part of this well construction.

2.1.3 Well development:

Well development was conducted more than 24 hours after grouting for the grout to gain enough strength. The well development was conducted using compressed air which was applied through the same thinner drilling rod extended close to the bottom of the well. Compressed air was sent through the drilling string and rod to the bottom of borehole and forces water out through the well and discharge pipe, discharging into the cutting bin (Air Burst Development). Well development took about two (2) hours with an average pumping rate of 15 L/s. Relatively clear water was obtained after about 15 minutes of development. Recovery to original water levels after stop of the well development took about one (1) hour.

Table 1 lists the properties of major supplies and materials used for the well construction.

Table 1. Supplies and Materials Consumed and Installed

Items	Length (m)	OD (cm)	Thickness (cm)	Material	Note
Temporary casing	15.0	32.5	1.0	Steel	Welded
Permanent casing	18.0	22.2	1.0	Stainless steel	Welded
Tremie pipe		3.7		PVC	Threaded
Portland cement	40 kg per bag			ASTM C150 CSA A3001	40 bags

2.1.4 Well Completion

FDC03RR was completed as a pitless well with the stainless steel casing stickup of 0.66 m. A vermin-proof well cap was installed to prevent the entry of surface water and other foreign material into the well. The completed well was tagged with a MECP well ID of A359261.

2.2 Cutting Sampling and Classification

Drilling cuttings were sampled approximately every 1.5 m of drilling advance. A total of 22 samples were taken. The cutting samples were collected by Palmer's staff and brought back to Palmer lab for further classification and study. Principles of sedimentology, petrography and general geological evolution were followed to classify the soil and bedrock cuttings. The following list provides the major factors that were considered in classifying cuttings:

- Cuttings are not a real reflection of soil and bedrock properties as rotatory drilling may change texture and sorting, and totally destroy structures;
- Sampling depth may be different from the real depth of the formations;
- Cutting samples may result from combination of soil and bedrock at different depths;
- Drilling pressure is usually inversely proportional to bedrock cutting size;
- Poorly "sorted" bedrock cutting sizes may attribute to discontinuities such as bedding planes, fractures and solution features;
- Rounded particles are indicators of native soil, and proportion of rounded particles and fragmented particles may provide clues to the position of overburden and bedrock boundary; and
- Cuttings are brought out by either air or mixture of air and water. Fine materials (fine sand, silt and clay) may be flushed out for formations containing fine materials. Fine materials may be created by rotatory grinding for formation of coarse grain size and bedrock.

The 22 cutting samples were classified based on the above principles and factors. Based on the classification of cutting samples, the formations under the site within the well depth is summarised from top down as follow:

- Fill sandy gravel to fill gravelly sand;
- Sandy gravel to gravelly sand;
- Dolostone – lightly weathered;
- Limestone;

- Interbedded dolostone and limestone – with vugs and fossil;
- Limestone; and
- Interbedded shale and siltstone.

Detailed information of each formation can be found in the well logs (**Appendix A**).

3. Pumping Test

A step-drawdown test (step test) and a 72-hour constant rate pumping test to assess well performance and aquifer properties properties was conducted between April 17 and May 4, 2023. The pumping was conducted in FDC03/RR (pumping well). Observation wells include the existing supply well on site (FDC03R) and the two monitoring wells to the east of the site (CM-03-03-S and CM-03-03-D). Well logs for the pumping well and observation wells are provided in **Appendix A**. **Figure 2** shows the well locations, and **Table 2** lists the details of the pumping and observation wells as well as instrumentation.

To permit the water taking for the pumping test, an Environmental Activity and Sector Registry (EASR) for a pumping test was registered with the MECP.

A pumping rate of 25 L/s was used for the pumping test, which is the same as the permitted pumping rate of the existing supply well on site (FDC03R). The pump intake was set at a depth of 24.0 mbgs to be set above the major water production zones.

Table 2. Details of Pumping Well and Observation Wells

Well	Elevation (masl)	Depth (m)	Diameter (cm)	Screen Interval (mbgs)	Distance to Pumping Well (m)	Logger (Frequency)
FDC03RR	273.0	33.0	20.0	17.5-33.0	-	2 (5 s,10 s)
FDC03R	273.0	33.0	15.0	17.8-32.9	14.0	1 (5 s)
CM-03-03 S	268.0	8.1	7.0	-	80	1 (10 min)
CM-03-03 D	268.0	27.0	10.0	13.4-27.4	80	1 (10 min)

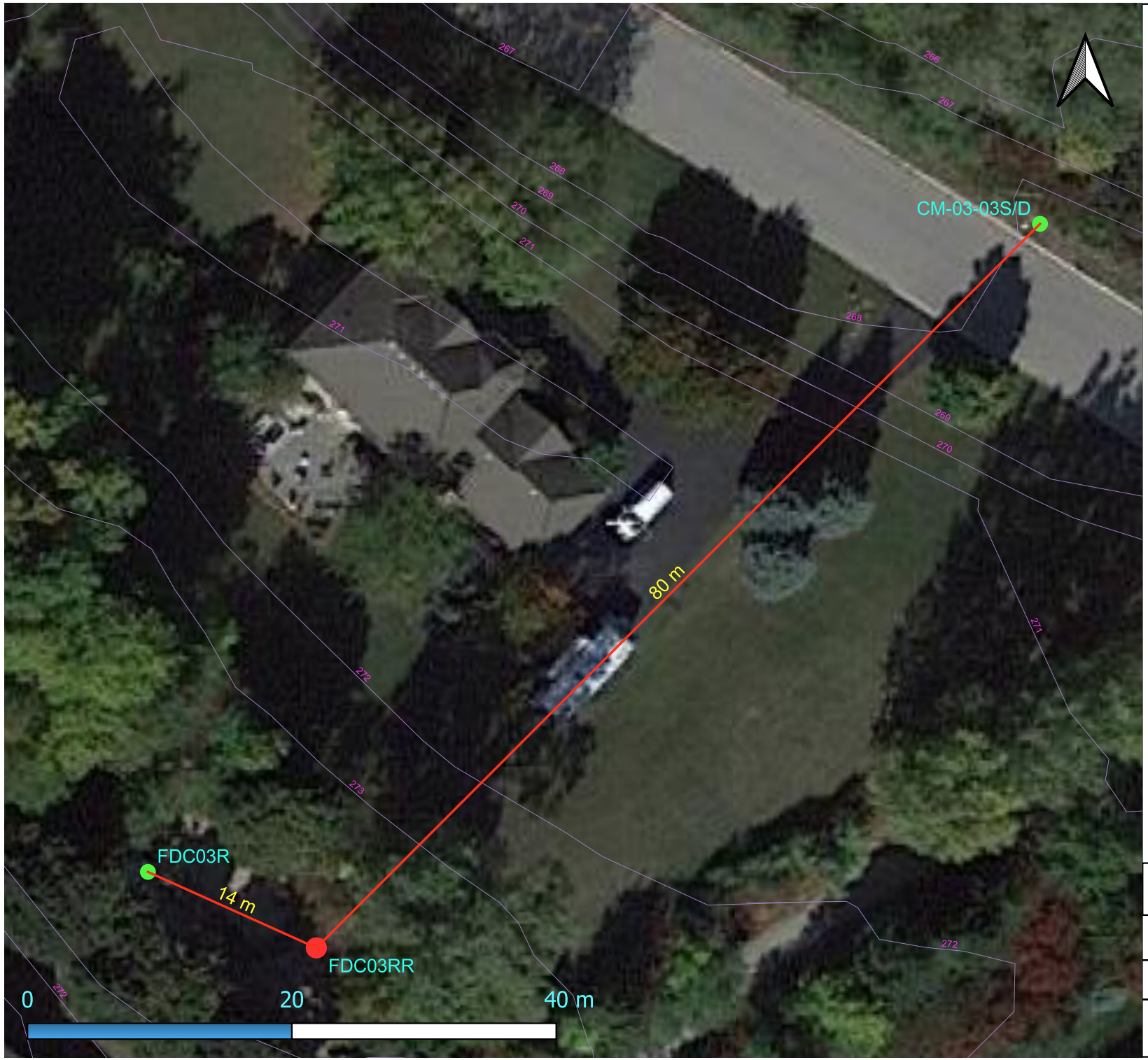
Two pressure transducers were installed into the pumping well (FDC03RR), which were set at different recording frequencies to ensure a backup in case of any mechanical issues and to calibrate each other. One pressure transducer was installed for each observation well (FDC03R, CM-03-03S and CM-03-03-D). Manual water level monitoring was conducted in the pumping well and observation wells during the test to match the pressure transducer data.

Erosion and flooding surveillance along the discharge route was conducted during the step test and 72-hour pumping test. No signs of erosion and flooding were identified (**Photo Album 2**).

3.1 Environmental Activity and Sector Registry

An EASR (Registration Number: R-011-1219635186) was registered in general accordance with the provincial Water Taking User Guide for Environmental Activity and Sector Registry. Two of the key documents include the Pumping Test Design Report and the Notification Letter. Palmer prepared these two documents following the provincial guides and based on its understandings of the site conditions.

The Pumping Test Design Report and the Notification Letter are provided in **Appendix B**.



LEGEND

Pumping Test Layout

- Pumping Well
- Observation Well
- Top Contours (1 m)

Step Test:

Pumping Rate (L/s)	Time to Stablize (Hour)
6.3	0.5
12.5	0.5
18.8	0.67
25	1.0

Constant Rate Test:

25L/s (396 gpm for 72 hours)

CLIENT
R.V. ANDERSON ASSOCIATES LIMITED

PROJECT
Carlisle Well Field, Hamilton, Ontario

TITLE
Pumping Test Layout

Palmer

REF. NO: 2108704

Figure 2

3.2 Step-Drawdown Test

A step-drawdown test (or step test) is a pumping test to investigate the performance of a supply well under a variable (stepped) pumping rate. In a step-drawdown test, the pumping rate in the pumping well is increased from an initially low constant rate through a sequence of pumping intervals (steps) of progressively higher constant rates. Each step is typically of equal duration, lasting from approximately 0.5 to 2 hours until groundwater levels become stabilized or close to stabilized. Each step should be of sufficient duration to allow dissipation of wellbore storage effects.

The step test was conducted on April 28, 2023 from 10:23 am to 1:10 pm, following closely the pumping test plan (**Appendix B**). 10 mm of rainfall occurred during the step test. Four steps of pumping rates were completed, with an increment of 6.25 L/s, one quarter of the maximal permitted pumping rate of 25 L/s. In order to estimate the sustainable pumping rate for the 72-hour pumping test, the pumping for the step test was conducted until the groundwater levels became stabilised or close to stabilization. **Table 3** summarizes the test results and **Figure 3** shows the step test hydrograph. A transmissivity from the step test was estimated based on the correlation between specific capacity and transmissivity developed by Eagon and Johe (1972) for fractured carbonate bedrock.

Table 3. Summary of Step Test

Step	Pumping Rate (L/s)	Drawdown (m)	Time to Stabilize (hour)
Initial water level: 9.77 mbtc			
Step 1	6.3	1.06	0.5
Step 2	12.5	2.45	0.5
Step 3	18.8	4.19	0.67
Step 4	25	6.22	1.0
End-of-test water level: 15.99 mbtr			
Recovery	Recovered 99.6% in one hour.		

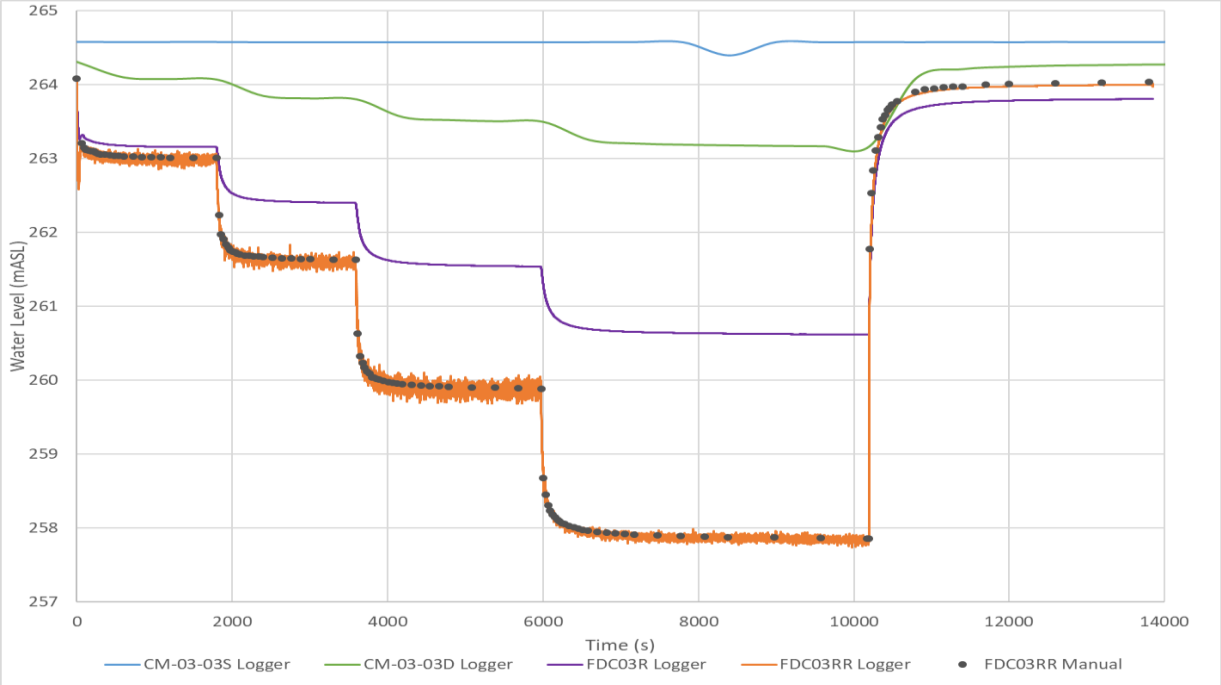
mbtc-meters below top of casing

Based on the time taken for groundwater level to stabilize during each step and the recovery speed of groundwater level after completion of the step test, the maximal permitted pumping rate of 25 L/s is sustainable during the step test.

During the step test, groundwater levels from FDC03R, CM-03-03-S, and CM-03-03-D were monitored. Hydrographs for pumping well and the observation wells are presented in **Figure 3**. As the hydrographs show, the shallow overburden monitoring well (CM-03-03-S) did not respond to the pumping, the deep monitoring well (CM-03-03-D) responded to pumping slightly. The response of the existing supply well (FDC03R) to pumping is well synchronized with that of the pumping well (FDC03RR).

I should be noted that the open hole start from 17.5 mbgs (**Appendix A**). The end-of-test water level is 15.33 mbgs, which is still about two (2) meters above the top of open hole.

Figure 3. Hydrographs of Step-Drawdown Test



3.3 72-Hour Constant Rate Pumping Test and Recovery

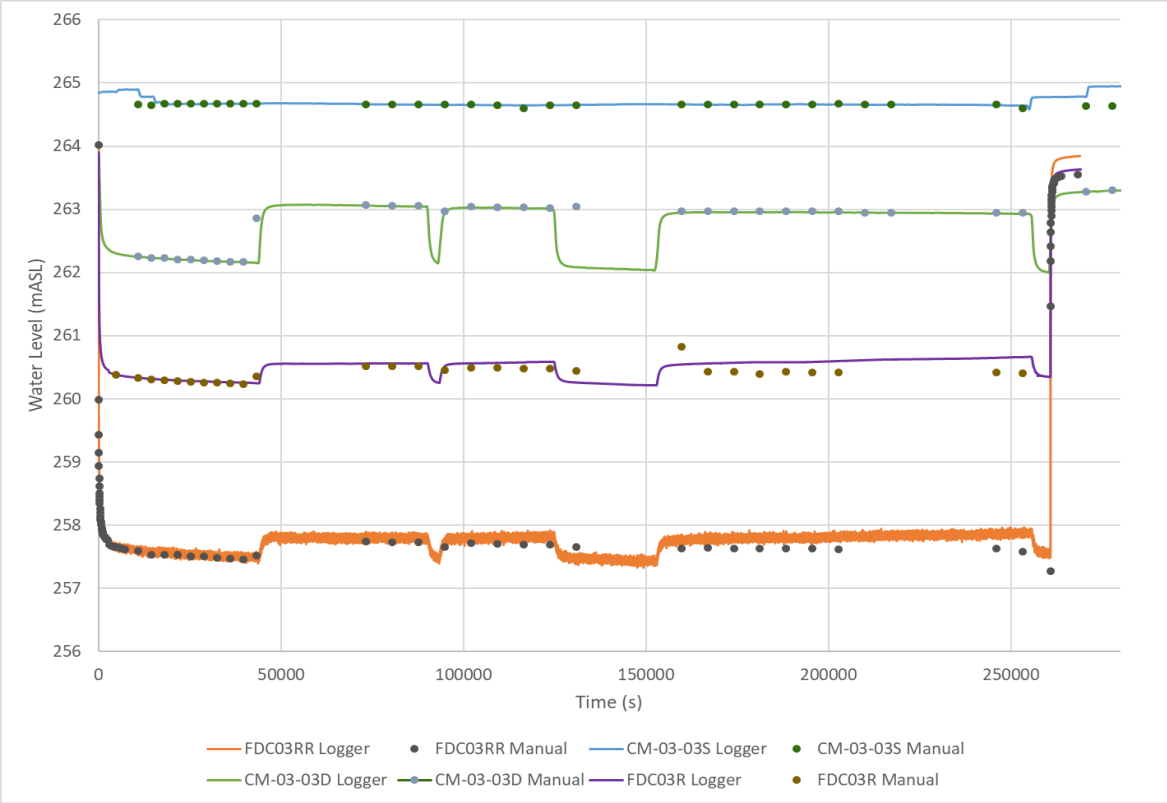
A long-term constant rate pumping test is carried out to assess well performance, well yield, the zone of influence of the well, aquifer characteristics, aquifer extent, presence of boundary conditions and possible hydraulic connection to surface water. Considering the bedrock aquifer is the major water production aquifer, 72-hours of pumping was adopted.

The 72-hour constant rate pumping test was conducted from 10:40 am of May 1 to 12:00 pm of May 4, 2023, following closely the Pumping Test and Discharge Plan (**Appendix B**). Rainfall occurred at a daily rate of 0.8 mm on May 1, 8.0 mm on May 2, 9.2 mm on May 3 and 5.4 mm on May 4, 2023 based on data assessed on May 11, 2023 from https://hamilton.weatherstats.ca. **Table 4** lists the summary of the 72-hour pumping test. Hydrographs for the pumping well and the observation wells are presented in **Figure 4**.

Table 4. Summary of 72-Hour Pumping Test

Well	Pumping Rate (L/s)	Time to Stabilize (hour)	Drawdown (m)	Screen Interval (mbgs)	Recovery
FDC03RR	25	0.83	6.35	17.5-33.0	98 % in 0.5 hours
FDC03R	-	0.83	3.60	17.8-32.9	91% in 0.5 hours
CM-03-03 D	-	0.83	2.0	13.4-27.4	85% in 0.5 hour
CM-03-03 S	-	-	0.06	-	-

Figure 4. Hydrographs for 72-Hour Pumping Test



As the hydrographs show, the response of groundwater levels in the existing supply well (FDC03R) and in the deep monitoring well (CM-03-03-D) to pumping is well synchronized with that of the pumping well (FDC03RR) without apparent time lag. The shallow monitoring well (CM03-03-S) responded very slightly to the pumping.

It should be noted that a few variances appear on the hydrographs for the three bedrock wells during the pumping test. The magnitude of the variances of CM03-03-D is much greater than that of the pumping well and the existing well, indicating the variances might be caused by pumping from other wells, with FDC05 being the most likely source. These variances do not affect the overall trends of the hydrographs. However, they will make the quantity assessment for FDC03RR more conservative.

4. Groundwater Sampling

The Groundwater Sampling and In-Situ Water Quality Monitoring Plan (the Sampling Plan) followed the procedures requested by the City of Hamilton for the purposes of drinking water quality assessment and GUDI condition assessment. **Table 5** lists the details of the Sampling Plan. Groundwater sampling and in-situ monitoring were executed closely following the plan except for the surface water as the creek north of the site was dry at all times except during periods of rain, thus sampling stream water would not provide representative data and information, and was not executed. As agreed with the City of Hamilton, the sampling for Ontario Drinking Water Quality Standards (ODWQS) for the two monitoring wells (CM-03-03-S and CM03-03-D) was conducted by the city as part of their routine monitoring, but Ultraviolent Transmittance (UVT) was monitored by Palmer as part of pumping test monitoring.

Table 5. Groundwater Sampling and In-situ Water Quality Monitoring Plan

Phase	Prior to Starting Pumping Test	24-hour	48-hour	72-hour
New Redundant Well				
FDC03RR	ODWQS Standard Package Pharmaceutical (Caffeine) Field Monitoring (incl. UVT)	ODWQS Standard Package MPA Analysis F-Colliphage Field Monitoring (incl. UVT)	ODWQS Standard Package MPA Analysis F-Colliphage Field Monitoring (incl. UVT)	ODWQS Full Package MPA Analysis Pharmaceutical (Caffeine) F-Colliphage ^{18}O and ^{2}H Age Dating Field Monitoring (incl. UVT)
Existing Municipal Well				
FDC03R	ODWQS Standard Package Field Monitoring (incl. UVT)	-	-	ODWQS Standard Package ^{18}O and ^{2}H Age Dating Field Monitoring (incl. UVT)
Monitoring Wells				
CM-03-03-S	ODWQS Standard Package (CH) Field Monitoring (incl. UVT)	-	-	ODWQS Standard Package(CH) Field Monitoring (incl. UVT)
CM-03-03-D	ODWQS Standard Package (CH) Field Monitoring (incl. UVT)	-	-	ODWQS Standard Package (CH) Field Monitoring (incl. UVT)
Surface Water Feature				
West Creek	ODWQS Standard Package Field Monitoring F-Colliphage	-	-	ODWQS Standard Package Field Monitoring Age Dating

Groundwater Sampling Quality Assurance and Quality Control

Groundwater sampling Quality Assurance and Quality Control (QA/QC) was implemented through following closely:

- The Pumping Test and Discharge Plan (**Appendix B**);
- Groundwater Sampling and In-situ Water Quality Monitoring Plan (**Table 5**);
- The sampling instructions from participating labs; and
- Generally accepted groundwater sampling practices in Ontario.

Generally accepted groundwater sampling practices includes but not limited to:

- Sampling water representative of aquifer;
- Cooling sample below 4 ^{o}C with ice pack and sealed coolers;
- Avoiding cross-contamination among samples, and between samples, tools and supplies;
- Clean platform for handling sample containers and samples;
- Wear nitrile gloves and masks when filling containers;
- Rinsing unpreserved containers two to three times before filling; and
- Order backup containers for unexpected damage of containers.

4.1 Groundwater Sampling for Ontario Drinking Water Quality Standards

In order to assess the drinking water quality, groundwater samples were collected from the pumping well (FDC03RR) and the existing supply well (FDC03R) following the above Sampling Plan. Groundwater samples were also collected from the observation wells (CM-03-03 S and CM-03-03-D) by City of Hamilton personnel.

To delineate the trend of water quality variation during the pumping test and in order to gain insight into GUDI conditions, four sampling events for the pumping well (FDC03RR) were conducted, this included one sample prior to the pumping test (baseline) and three samples at approximately 24, 48 and 72 hours, respectively, throughout the pumping test. The first three samples were submitted for an ODWQS standard package while the final sample was submitted for a ODWQS full package. Two sampling events for the existing supply well (FDC03R) which included a sample before the pumping test and one near the end of the pumping test followed the above sampling plan.

ODWQS standard package covered all chemical parameters listed in O. Reg.169/03 and O. Reg.457/16, while the ODWQS full package covered all parameters listed in O. Reg.169/03, O. Reg.457/16, and including additional microbiological parameters, chemical parameters, and radiological parameters.

The chemical analysis was completed by the City of Hamilton Environmental Laboratory. The results of analysis are provided in **Appendix C**.

Table 6 list the major constituents, indicative parameters and parameters of exceedances over the ODWQS for the sampling events for FDC03RR and FDC03R. **Table 7** lists the concentrations of major constituents,

indicative parameters and parameters that exceed the ODWQS for groundwater samples taken from CM-03-03-S and CM-03-03-D.

It should be noted that the TSS of 49.6 mg/L for FDC03R for April 17, 2023 sampling event is abnormal, which may be caused by sampling and testing process. Another observation is that the sodium concentrations for all sampling events from all wells exceed the reporting limits of 20 mg/L.

Table 6. Major Constituents and Exceedances for FDC03RR and FDC03R

Analyte	Units	ODWS	FDC03RR				FDC03R	
Date of Sampling			**May 1, 23**	**May 2, 23**	**May 3, 23**	**May 4, 23**	**April 17, 23**	**May 4, 23**
Alkalinity	mg/L	-	346	341	322	339	331	324
Ammonia + Ammonium as N	mg/L	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chloride	mg/L	-	107	97.6	97.8	95.9	68.5	74.1
Conductivity	umhos/cm	-	1080	1020	1020	1030	868	913
Dissolved Organic Carbon	mg/L	-	0.7	0.7	0.6	0.8	0.7	1.0
Fluoride	mg/L	1.5	0.07	0.07	0.07	0.07	0.07	0.07
Nitrate as N	mg/L	10	0.16	0.29	0.38	0.44	0.91	1.81
Nitrate + Nitrite as N (Calculation)	mg/L	-	0.16	0.29	0.38	0.45	0.91	1.81
Nitrite as N	mg/L	1	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
o-Phosphates as P	mg/L	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
pH	pH	-	7.53	7.96	7.70	7.78	7.77	7.89
pH-Saturation	pH	-	6.88	6.9	6.88	6.87	6.89	6.89
Silica-Reactive	mg/L	-	10.7	10.4	10.4	10.3	9.77	10.1
Sulphate	mg/L	-	74.9	75.1	75.4	74.0	61.5	57.0
Total Suspended Solids (TSS)	mg/L	-	<0.6	<0.6	<0.7	-	*49.6*	3.7
Turbidity	NTU	-	0.44	0.13	0.14	0.10	2.24	6.52
Aluminum	mg/L	-	0.008	<0.002	<0.002	<0.002	0.344	0.239
Calcium	mg/L	-	114	108	118	116	116	111
Hardness	mg/L	-	432	414	442	437	436	420
Iron	mg/L	-	0.027	0.017	0.014	0.011	1.87	0.933
Lead	mg/L	0.01	0.0002	0.0002	0.0002	0.0002	0.0007	0.0004
Potassium	mg/L	-	1.61	1.57	1.64	1.63	1.81	3.48
Sodium	mg/L	20	62.9	56	56.5	56.1	39	43.3
E. coli	MPN/100mL	0	0	0	0	0	0	0
Total Coliform	MPN/100mL	0	0	0	0	0	0	0

Table 7. Major Constituents and Exceedances for CM-03-03-S and CM03-03-D

Analyte	Units	ODWS	CM-03-03-D	CM-03-03-D	CM-03-03-S	CM-03-03-S
Date of Sampling	**-**	**-**	**April 11, 23**	**May 10, 23**	**April 11, 23**	**May 10, 23**
Alkalinity	mg/L	-	302	308	393	363
Ammonia + Ammonium as N	mg/L	-	<0.01	<0.01	<0.01	<0.01
Chloride	mg/L	-	83.1	81.0	263	130
Conductivity	umhos/cm	-	897	906	1680	1170
Dissolved Organic Carbon	mg/L	-	1.2	1.1	1.2	1.4
Fluoride	mg/L	1.5	0.06	0.07	0.04	0.05
Nitrate as N	mg/L	10	2.2	2.63	3.62	3.06
Nitrate + Nitrite as N (Calculation)	mg/L	-	2.26	2.63	3.62	3.06
Nitrite as N	mg/L	1	<0.01	<0.01	<0.01	<0.01
o-Phosphates as P	mg/L	-	<0.05	<0.05	<0.05	<0.05
pH	pH	-	7.71	7.75	7.68	7.6
pH-Saturation	pH	-	6.97	6.97	6.76	6.86
Silica-Reactive	mg/L	-	9.82	10.1	16.6	16.3
Sulphate	mg/L	-	49	47.5	90.5	57.3
Total Suspended Solids	mg/L	-	2.7	3.6	<1	1.6
Turbidity	NTU	-	9.77	6.41	0.39	0.72
Aluminum	mg/L	-	0.002	<0.002	0.006	0.02
Calcium	mg/L	-	102	101	150	117
Hardness	mg/L	-	376	391	489	393
Iron	mg/L	-	1.4	2.02	0.015	0.027
Lead	mg/L	0.01	<0.0001	<0.0001	<0.0001	<0.0001
Potassium	mg/L	-	1.38	1.43	0.39	0.34
Sodium	mg/L	20	42.8	46.2	153	107
E. coli	MPN/100mL	0	0	0	0	0
Total Coliform	MPN/100mL	0	1	0	0	2

4.2 Groundwater Sampling for Pharmaceutical Parameters

The occurrence of pharmaceutical compounds is found to be strongly correlated with the presence of modern water and with occurrence of other anthropogenic compounds. Available studies have reported that concentrations of pharmaceuticals in surface waters, groundwater and partially treated water are typically less than 0.1 µg/L (or 100 ng/L), and concentrations in treated water are generally below 0.05 µg/L (or 50 ng/L) (2012, WHO).

In order to assess impact of pharmaceutical compounds to drinking water quality and gain insights into GUDI conditions of FDC03RR, groundwater sampling for the pharmaceutical compounds, caffeine, was conducted for the pumping well at the beginning and near the end of pumping test following the above sampling plan.

The chemical analysis was completed by the City of Hamilton Environmental Laboratory. The results of analysis are provided in **Appendix C**. **Table 8** lists the summary of the test results, which shows that all test results are under minimum detection limit.

Table 8. Test Results of Caffeine

Well ID	Types	Unit	MDL*	Beginning of Pumping	72-Hour
FDC03RR	Caffeine	ug/L	0.5	<0.5	<0.5

***Minimum Detection Limit**

4.3 Groundwater Sampling for Microscopic Particulate Analysis

Microscopic Particulate Analysis (MPA) is intended to identify organisms that occur in surface waters and whose presence in groundwater suggests that at lease part of the source of water is surface water. The parameters that are believed to be indicators of surface water contamination of groundwater include Giardia lamblia cysts, Coccidia, diatoms, algae, insects/larvae, rotifers, and chlorophyll-containing plant debris.

For the purpose of GUDI assessment, three groundwater sampling events for the pumping well (FDC03RR) for MPA were conducted at approximately 24, 48 and 72 hours, respectively, following the above sampling plan. Following the guides of the York-Durham Regional Environmental Laboratory, a grab sample of 20 litres of water was taken with a carboy during each sampling occasion. The samples were delivered to lab within 48 hours.

The chemical analysis was completed by York-Durham Regional Environmental Laboratory. The results of analysis are provided in **Appendix C**. **Table 9** lists the summary of the test results. Only two types of particulates, pollen and Nematodes eggs, were identified, and the number of particulates ranged from 60 to 240, suggesting recharge from surface water sources but not necessarily indicative of a GUDI well.

Table 9. Test Results for MPA

Particulate)	MPA-1 (24-Hour)	MPA-2 (48-Hour)	MPA-3 (72-Hour)
Pollen	120	60	240
Nematodes, eggs	-	60	60

4.4 Groundwater Sampling for F-Coliphage

F-specific bacteriophages, also known as sexual coliphages or male-specific bacteriophages is composed of multiple groups of bacteriophages that infect bacteria via the F-specific pili (F-pili) and contain members with single-stranded DNA genomes (F-specific DNA [F-DNA] coliphages) or RNA genomes (F-specific RNA

[F-RNA] coliphages). Coliphages are viruses that are infective for E. coli and have recently been considered indicators of fecal contamination, in addition to the standard fecal indicator, fecal coliform bacteria (Paul and Kellogg, 2000). Owning to the viral structures of coliphages, compared with bacterial indicators, coliphages are more resistant to disinfection and diffuse further distances from pollution sources. Therefore, coliphage presence may serve as a better predictor of groundwater quality.

To assess the impact of fecal contamination and gain insights into GUDI conditions of the pumping well (FDC03RR), three groundwater sampling events for F-Coliphage were conducted at approximately 24, 48 and 72 hours, respectively, of the pumping test following the above sampling plan. Following the guides of the York-Durham Regional Environmental Laboratory, a grab sample of 0.2 litres of water was taken with two bottles during each sampling event. The samples were delivered to lab within 48 hours.

The chemical analysis was completed by York-Durham Regional Environmental Laboratory. The results of analysis are provided in **Appendix C**. **Table 10** lists the summary of the test results.

Table 10. Test Results for F-Coliphage

Types	24-Hour	48-Hour	72-Hour
Male-Spec. Coliphage: DNA+RNA	0	0	0
Male-Spec. Coliphage: RNA	0	0	0

4.5 In-Situ Ultraviolet Transmission Measurement

Ultraviolent Transmittance (UVT) is a measurement of the amount of ultraviolet light at 254 nanometers (nm) of wavelength that is able to pass through 10 mm of water. The UVT is expressed as a percentage of UVT. The amount of light that gets through the water sample can be an indicator of the general water quality. A UVT of 100 percent indicates that, for a given wavelength, all of the light is able to pass through water with no losses from contaminants, like dissolved organics or particulate matter.

Palmer used a Real UV254 Field Meter to complete the in-situ UVT monitoring during the pumping test for both the pumping well (FDC03RR), the existing supply well (FDC03R) and the observation wells (CM-03-03 S and CM-03-03-D) as required by the above sampling plan. **Table 11** lists the UVT monitoring results. The monitoring results shows that:

- Based on UVT data, water quality from both FDC03RR and FDC03R is good;
- Low reading from CM-03-03-S result from high turbidity of water originating from porous overburden medium; and
- High reading from CM-03-03-D results from the low turbidity of groundwater originating from bedrock aquifer. The upward trending of the readings in CM-03-03-D may result from the groundwater flow induced by the pumping test.

Table 11. Ultraviolet Transmission Measurement

Well	Prior to Pumping	24-Hour	48-Hour	72-Hour
FDC03RR	100	100	100	100

Well	Prior to Pumping	24-Hour	48-Hour	72-Hour
FDC03R	100	-	-	100
CM-03-03-S	4.0	-	-	4.0
CM0-03-03-D	80.0	-	-	89.0

4.6 Groundwater Sampling for Oxygen-18 and Deuterium

In natural water with normal composition, among 10^6 water molecules of $^1H_2{}^{16}O$, there are about 2000 molecules $^1H_2{}^{18}O$ with heavy oxygen isotope ^{18}O, and 160 molecules $^2H^1H^{16}O$ with one hydrogen atom being replaced by ^2H (Deuterium). The differences in isotopic abundance were caused by isotope fractionation. Isotope fractionation is a process of separation of isotopes of an element during naturally occurring processes as a result of the mass differences between their nuclei, and may include evaporation or condensation, melting or crystallization, diffusion through crystals, and isotopic exchange reactions.

The most prominent isotope fractionation in water cycle is evaporation, condensation and changes of state. When water evaporates into the air, the water vapour will be enriched in the lighter isotope and water left will be enriched with heavier isotopes.

The divergence of the isotopic abundance ratio (R_{sample}) of a sample in relation to a reference ($R_{reference}$) is specified with a delta(δ)-value, given in per mille (‰), as shown in the following equation.

$$\delta = \frac{R_{sample} - R_{reference}}{R_{reference}}$$

Take oxygen in water for example:

$$\delta^{18}O_{sample\text{-}SMOW} = [(^{18}O/^{16}O)_{sample} / (^{18}O/^{16}O)_{VSMOW} - 1] \times 1000‰$$

The reference used is the international standard V-SMOW (Vienna Standard Mean Ocean Water). Global statistics found that a linear correlation of δ^2H and $\delta^{18}O$ exists for fresh meteoric water as follow:

$$\delta^2H = 8 \times \delta^{18}O + 10‰ \text{ (Craig 1961)}$$

This equation depicts a Precipitation (or Meteoric Water) Line. Groundwater samples with analysis results plot close to the meteoric water line should be recharged by local precipitations and, hence, originate from meteoric water.

Two isotope samples were taken near the end of 72-pumping test, one from the pumping well (FDC03RR), and one from the existing supply well (FDC03R). The samples were delivered to the University of Waterloo's Environmental Isotope Laboratory for analysis. **Table 12** summarizes the details of the isotope sampling and analysis results, and the analysis results are provided in **Appendix C**.

Figure 5 shows the meteoric water line and the points of the analysis results. It is apparent that analysis result points are close to the meteoric water line, indicating that the groundwater from the pumping well

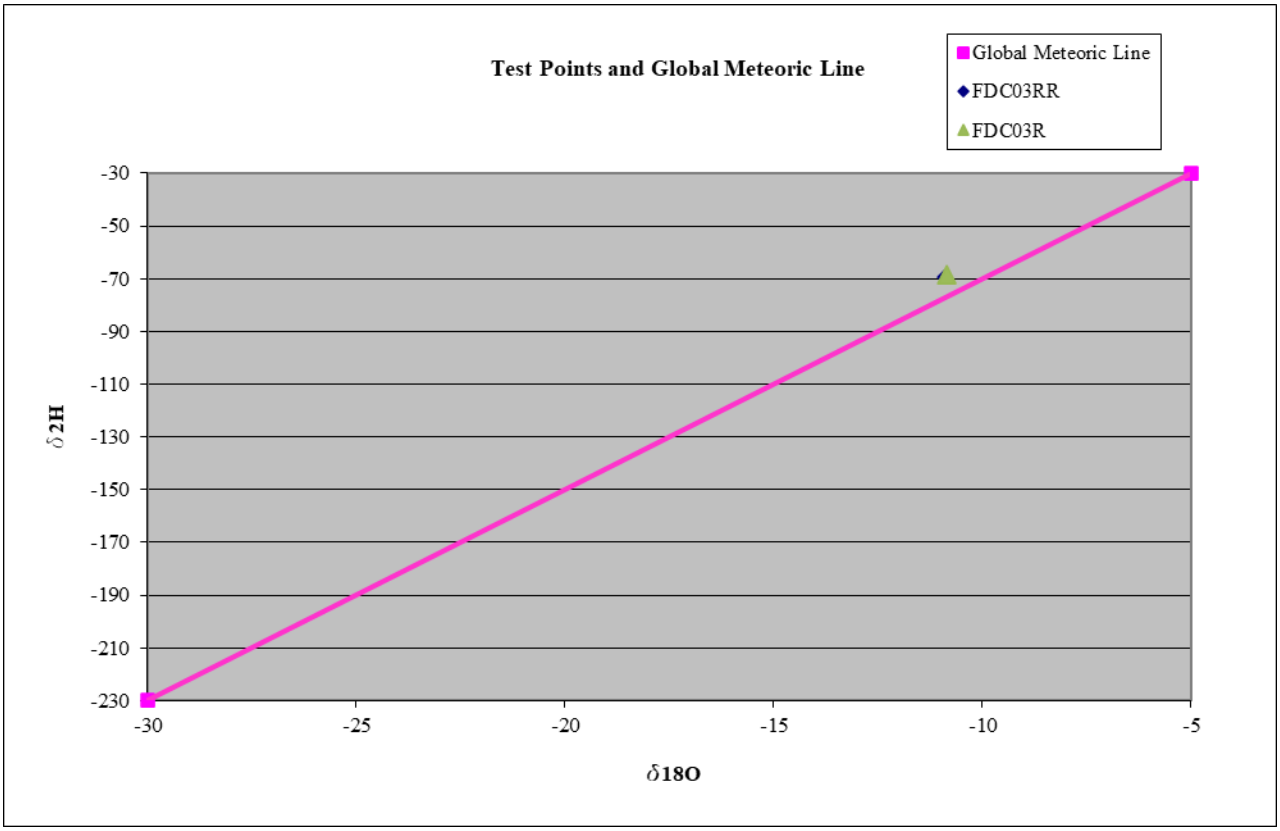
(FDC03RR) and existing supply well (FDC03R) are likely correlated to precipitation through receiving recharge of local precipitation.

It is noted that the City of Hamilton may have isotopic analysis results for precipitation water, which can be used to refine the above Precipitation Line equation. However, it is beyond the scope of work of current project.

Table 12. Isotope Sampling and Analysis Results

Well	pH	SPC (uS/cm)	δ ^{18}O	δ ^{2}H
FDC03RR	7.25	1040	-10.91	-69.18
FDC03R	7.29	930	-10.84	-68.34

Figure 5. Isotope Trendline



5. Performance of FDC03RR and Aquifer Assessment

Based on regional geology information available from the Ontario Geological Survey, the site is underlain with stratified ice-contract overburden deposits and bedrock of the Amabel Formation, which consists of primarily dolostone. Based on cutting classification (**Appendix A**), the formations encountered during drilling under the site is generally similar to the regional geology information. The stratified ice-contract deposits have moderately high capacity for taking groundwater recharge, but still provides moderate protection of the underlying bedrock aquifer against contamination.

The Amabel Formation is the regional aquifer that supplies abundant clean water in many areas along the top of Niagara Escarpment. Fractures, joints, solution enhancement, and other secondary porosity features provide the major spaces for storing and transmitting groundwater through the bedrock.

5.1 Well Parameters and Characteristic Drawdowns

As presented above, the major well parameters and their values for FDC03RR include:

- Well depth (D_w) = 33.0 m;
- Static groundwater level (H_s) = 10.0 mbgs;
- Pump intake depth (H_i) = 24 mbgs;
- Top of the bedrock aquifer (Ha) = 17.5 mbgs; and
- Pumping water level (H_{pu}) (at 25 L/s) = 15.4 mbgs.

Drawdown is defined as the change in groundwater levels caused by an applied stress, such as pumping from a well, pumping from a nearby well, or intensive water taking from the local area as well as seasonal declines. Drawdown in a supply well caused by pumping consists of five types of drawdowns, maximal drawdown, available drawdown, allowable drawdown, pumping drawdown and residual drawdown.

The maximum drawdown (s_m) is the maximal potentially usable drawdown and equals to the well depth minus static groundwater level.

In bedrock aquifer, the available drawdown (s_{av}) is the difference between the static water level and the top of the main water production zone (H_{pr}) when the pump intake is set lower than the main water production zone, or the difference between the static water level and the pump intake depth when the pump intake is set higher than the main water production zone.

Allowable drawdown (s_{al}) is determined for the protection of sensitive natural features or the prevention of deterioration of groundwater quantity and quality. No sensitive feature is anticipated to be impacted by the pumping of FDC03RR. However, drawdown lower than the top of the bedrock aquifer may lead to abrupt change of groundwater quality and aquifer mining. Allowable drawdown for FDC03RR should equal to the difference between the static water level and the top of the bedrock aquifer.

Pumping drawdown (or production drawdown) (s_p) is defined as the difference between the static water level and the pumping water level for a certain pumping rate.

Residual drawdown (S_r) is defined as the difference between the pumping drawdown and the available or allowable drawdown.

Table 13 is a summary of the values of well parameters and the five types of drawdowns. It is noted that the available drawdown should be adjusted based on the position of the major production zone delineated with well logging as recommended below. **Table 13** lists the two residual drawdowns, which to adopt depends on operation policies of the well field.

Table 13. Summary of Well Parameters and Characteristic Drawdown

Well Parameter (m)		Characteristic Drawdown (m)
Well Depth (D_w)	33.0	Maximum drawdown (s_m)= D_w – H_s = 23
Static Level (H_s)	10.0	Available drawdown (s_{av})= Hi – H_s = 14
Intake Depth (H_i)	24.0	Allowable drawdown (s_{al}) = H_a – H_s = 17.5 – 10 = 7.5
Top of Bedrock Aquifer (H_a)	17.5	Pumping drawdown (s_p)= H_{pu} – H_s = 5.4 (25 L/s)
Pumping water level (Hpu) (at 25 L/s)	15.4	Residual drawdown (s_r) = s_{av} – s_p = 14 – 5.4 = 9.4
		Residual drawdown (s_r) = s_{al} – s_p = 7.5 – 5.4 = 2.1

5.2 Well Performance Assessment for FDC03RR

The step test was conducted to assess the performance of the redundant well, FDC03RR. Major well performance parameters include specific capacity and well loss.

Well specific capacity was estimated with results of step test. **Table 14** summarized the well specific capacity values for each step of pumping. The specific capacity ranges from 14.5 to 21.4 m^3/hr/m (348 to 513.6 m^3/day/m), decreasing with increased pumping rate.

Table 14. Well Specific Capacity

Step	Pumping Rate (L/s)	Drawdown (m)	Time to Stabilize (hour)	Specific Capacity	
				(m^3/hr/m)	(m^3/day/m)
Step 1	6.3	1.06	0.5	21.4	513.6
Step 2	12.5	2.45	0.5	18.4	441.6
Step 3	18.8	4.19	0.67	16.2	388.8
Step 4	25	6.22	1.0	14.5	348

Well Loss (s_w) is calculated with the following Jacob (1947) equation:

$s_w = C \times Q^2$

C is Well Loss Constant (or Turbulence Factor) and is estimated with equation:

$C = (\Delta s_i/\Delta Q_i - \Delta s_{i-1}/\Delta Q_{i-1})/(\Delta Q_i + Q_{i-1})$

Q = pumping rate (L/s);
s_w = Well loss (m);
C = well loss constant ($m/(m^3/hr)^2$);
ΔQ_i = pumping rate incremental (L/s);
Δs_i = drawdown for each step (m).

Based on step test results and the above equations, C values range from 2.8×10^{-4} to 3.4×10^{-4} $m/(m^3/hr)^2$, and the well loss of the pumping well (FDC03RR) at the pumping rate of 25 L/s is 1.1 m. This indicates that the well is moderately efficient.

C value also provide a qualitative measure of well efficiency. Based on Walton (1970) scale, the C values 2.8×10^{-4} to 3.4×10^{-4} $m/(m^3/hr)^2$ (or 1.0 to 1.2 min^2/m^5) indicate that the well is of moderate efficiency.

The result of analysing the step test result with AQTESOLV (**Appendix D**) shows that the modelled well loss is zero, indicating the well is very efficient.

As shown with **Table 3** and **Figure 3**, groundwater levels stabilized within 0.5 hour at pumping rates of 6.3 and 12.5 L/s, while groundwater levels stabilized at about 0.7 and one hour respectively at rates of 18.8 and 25 L/s. The groundwater levels recovered to 97% in one hour following the completion of the step test. The fast stabilization and recovery indicate that the aquifer was not stressed much at these pumping rates.

Well efficiency is the ratio between theoretical drawdown and the actual drawdown measured. The theoretical drawdown was estimated with the following Theis (1935) equation:

$s_{th} = [\ Q / (4\pi T)\ ] \times W(u); \quad u = (r^2 S / 4Tt);$

The parameters and their values are as follows:

s_{th} = theoretical drawdown;
W(u) = well function;
S = Storage coefficent
T = transmissivity = 589 m^2/day (see below)
r = 0.1 m
t = time pumping = 10840 s = 3.0 hour = 0.125 day
Q = pumping rate = 25 L/s

s_{th}= 6.01 m.

The recorded actual drawdown s_{ac} = 5.71 m.

Well efficiency = 6.01/5.71 = 105%.

In summary, the well loss value shows that the well is efficient, and the well efficiency value shows that the well is highly efficient. Considering both well loss and well efficiency, it is reasonable to conclude that FDC03RR is efficient.

5.3 Aquifer Assessment

Both the step test and the 72-hour pumping test provide information about the aquifer. However, the 72-hour pumping test would stress a large volume of the aquifer and produce a large influence zone, and therefore the test results will provide information on larger area of aquifer. The aquifer will be assessed based mainly on the 72-hour pumping test results.

5.3.1 Structure of Aquifer

Drawdown data for the step test and 72-hour pumping test for the pumping well were both analysed with the commercially available software AQTESOLV. Best matches of recorded curves and the type curves were achieved with the confined aquifer model of Papadopulos-Cooper, which applies to both overburden aquifer and bedrock aquifer.

Based on the form of the drawdown – log time curve for the pumping well, the aquifer belongs to the confined aquifers with a leaking confining layer with certain level of storage. This observation is supported by the stratigraphy of stratified ice-contact deposits overlying carbonate bedrock.

Figure 4 shows that the response of groundwater level in CM-03-03-D to pumping is almost instantaneous, which is due to the fast expansion of the cone of depression. The instantaneous response to pumping suggests that the aquifer is confined.

Groundwater levels in the overburden well (CM-03-03-S) during the 72-hour pumping test (**Figure 4**) showed minimal response to pumping, indicating that the overburden is somewhat isolated from groundwater in bedrock aquifer. This is mainly due to the difference in the hydraulic conductivity between the bedrock and the overburden soils.

Consequently, the aquifer should be treated as a confined aquifer with weak leaking confining layer.

As shown in **Figure 4**, groundwater levels from both pumping well and observation wells became stabilized within one hour of pumping and recovered to over 80% within 0.5 hour, and the groundwater levels kept more or less constant all the time during pumping. These findings suggest that no hydraulic boundary was encountered within the influence zone of pumping.

5.3.2 Transmissivity, Storativity and Hydraulic Conductivity

Data collected from the step test and the 72-hour pumping test were analyzed using multiple methods to estimate the Transmissivity, storativity and resulting hydraulic conductivity values of the bedrock aquifer. The results of multiple methods will calibrate each other and help ensure analysis quality.

Empirical Correlation between Well Specific Capacity and Transmissivity:
The following correlation for fractured carbonate rock (Eagon and Johe 1972): was used to estimate transmissivity from the well specific capacity obtained during the step test. **Table 15** provides a summary of the results.

$$T=3.24 \times Sc^{0.81}$$

Table 15. Transmissivity Estimated from Well Specific Capacity

Step	Pumping Rate (L/s)	Drawdown (m)	Time to Stabilize (hour)	Specific Capacity (m^2/hr)	T (m^2/day)
Step 1	6.3	1.06	0.5	21.4	508
Step 2	12.5	1.39	0.5	18.4	1006
Step 3	18.8	1.74	0.67	16.2	825
Step 4	25	2.03	1.0	14.5	142

Curve Matching for Step Test Hydrograph:
Data from the step test for the pumping well was analysed with AQTESOLV using the confined Theis model. The following transmissivity and storativity values were obtained. The analysis results are provided in **Appendix D**.

T = 0.005184 m^2/s = 448 m^2/day
S = 0.0008802

It was also found that the data best matched the type curve of confined aquifer model, indicating the aquifer is under confined condition.

Curve Matching for 72-Hour Pumping Test Hydrograph of FDC03RR:
72-hour pumping test hydrograph for the pumping well was analysed with AQTESOLV (confined Papadopulos-Cooper model). The following transmissivity and storativity values were obtained. The analysis results are provided in **Appendix D**.

T = 0.01103 m^2/s = 953 m^2/day
S = 9.0×10^{-11}

It should be noted that the S value is too low based on published values for the Amabel Formation, and this value should not be relied on.

Curve Matching for 72-Hour Pumping Test Hydrograph of FDC03R:
72-hour pumping test hydrograph for the FDC03R was analysed with AQTESOLV (confined Papadopulos-Cooper model). This method eliminated the influence of well storage and well loss. The following transmissivity and storativity values were obtained. The analysis results are provided in **Appendix D**.

T = 0.01388 m^2/s = 1200 m^2/day

$S = 1.0 \times 10^{-10}$

Curve Matching for 72-Hour Pumping Test Hydrograph of CM-03-03-D

72-hour pumping test hydrograph for the FDC03R was analysed with AQTESOLV (confined Papadopulos-Cooper model). This method eliminated the influence of well storage and well loss. The following transmissivity and storativity values were obtained. The analysis results are provided in **Appendix D**.

$T = 0.02102\ m^2/s = 1820\ m^2/day$
$S = 4.0 \times 10^{-9}$

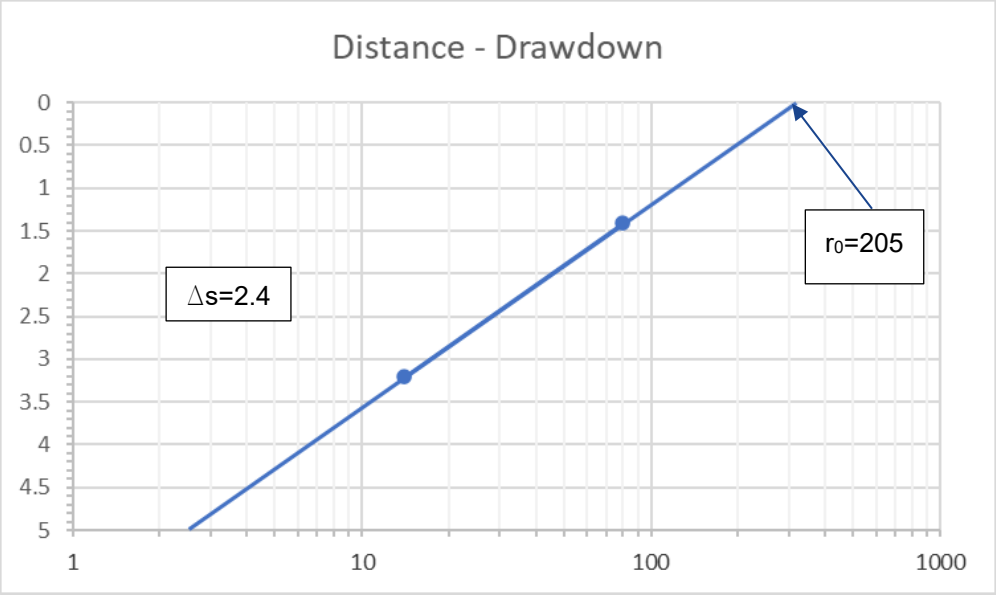
Distance – Drawdown Analysis:

Distance – drawdown analysis has been conducted on the equilibrized drawdown from the existing supply well (FDC03R) and the deep observation well. The data used for the analysis is listed in **Table 16**. The distance – drawdown curve is shown in **Figure 6**. It should be noted that as distance – drawdown analysis brings data points covering large area into the equation, the estimated T and S values should reflect the properties of larger area of aquifer.

Table 16. Data for Distance-Drawdown Analysis

Time (s)	Observation Well	Drawdown (m)	Distance (m)
5000	FDC03R	3.21	14
	CM-03-03-D	1.41	80

Figure 6. Distance - Drawdown Curve



The values of transmissivity and storativity were calculated with the following equations:

$T=2.3Q/(2\ \pi\Delta s)$;
$S=2.25Tt/r_o^2$

T = 0.0038 m^2/s = 329 m^2/day;
S = 0.00102

Summary of Transmissivity (T value) and storativity (S value) and hydraulic Conductivity (K value):
As presented above, T and S values were estimated with four methods as follows:

- Step test correlation: T = 0.00718 m^2/s = 620 m^2/day
- Step test curve match: T = 0.005184 m^2/s = 448 m^2/day; S = 0.0008802
- 72-hour pumping test curve match-FDC03RR: T = 0.01103 m^2/s = 953 m^2/day; S = 9.0 x 10^{-11}
- 72-hour pumping test curve match-FDC03R: T = 0.01388 m^2/s = 1200 m^2/day; S = 1.0 x 10^{-10}
- 72-hour pumping test curve match-CM-03-03-D: T = 0.02102 m^2/s = 1820 m^2/day; S = 4.0 x 10^{-9}
- Distance – drawdown method: T = 0.0038 m^2/s = 329 m^2/day; S = 0.00102

The T values from different methods fall into similar ranges with the 72-hour pumping test resulting in the maximal value. The average T value is 0.01035 m^2/s = 895 m^2/day.

Assuming the thickness of the bedrock aquifer being 18.5 m, the hydraulic conductivity (K values) from the different methods are as follows:

- Step test correlation: K = 3.9 x 10^{-4} m/s
- Step test curve match: K = 2.8 x 10^{-4} m/s
- 72-hour pumping test curve match-FDC03RR: K = 6.0 x 10^{-4} m/s
- 72-hour pumping test curve match-FDC03R: K = 7.5 x 10^{-4} m/s
- 72-hour pumping test curve match-CM-03-03-D: K = 1.1 x 10^{-3} m/s
- Distance – drawdown method: K = 2.1 x 10^{-4} m/s

It should be noted that the storativity value from the 72-hour pumping test is too low, which may be caused by software (Willis D. and John L. 2000). The storativity values from step test and distance – drawdown analysis fall into same order, therefore, the average storativity value from these two methods is adopted, which is S = 0.00095.

5.3.3 Sustainable Yield

Sustainable yield is defined as the amount of water that can be pumped from the well continuously over time without causing damage to the well (too much drawdown) or causing the well to go dry and is usually assessed with the aquifer parameters. Two methods are adopted to estimate the sustainable yield: Farvolden Method and van der Kamp and Maathuis Method.

Farvolden Method established a relationship between a 20-year safe pumping rate (Q_{20}), T value and available drawdown (H_a) where:

$$Q_{20} = [4\pi T(H_a/8)/2.3]S_f$$

S_f is safety factor;
Ha = available drawndown.

Using T = 895 m^2/day (average T), H_a = 14 m, S_f = 0.7
Q_{20} = 69 L/s.

van der Kamp and Maathuis Method established a relationship between a 20-year safe pumping rate (Q_{20}), pumping rate during pumping test (Q), T value, available drawdown (H_a), drawdown at 100 minutes pumping (S_{100min}), and 20 year theoretical drawdown ($S_{T20years}$) and 100 minute theoretical drawdown ($S_{T100min}$).

$$Q_{20} = (S_f H_a Q)/[S_{100min} + (S_{T20yrs} - S_{T100min})]$$

S_f is safety factor.

Using T = 895 m^2/day (average T), H_a = 14 m, Q = 25 L/s = 2160 m^3/day, S_{100min} = 6.39 m, S_f = 0.7.
S_{T20yrs} and $S_{T100min}$ was estimated with Theis (1935) equation with a value of 5.39 and 3.17 m respectively.
Q_{20}= 29 L/s.

The averaged sustainable yield value from the above two methods = 49 L/s

Based on the above analysis, the sustainable yield of the well and aquifer ranges from 29 to 69 L/s, averaged at 49 L/s, which is above the permitted pumping rate 25 L/s, which suggests that the pumping well (FDC03RR) meets the requirement of water quantity.

As shown in **Figure 4**, groundwater levels stabilized approximately one hour after starting of the pumping test. With the exception of well interference with the existing production well network in Carlisle, the data shows no apparent fluctuation during the 72-hour of pumping, suggesting that aquifer mining did not occur during the pumping test.

5.3.4 Influence Zone and Well Interference

Two methods to estimate the influence zone and well interference were used, including forward analysis with AQTESOLV (Papadopulos-Cooper model) and Theis distance-drawdown analysis based on T = 895 m^2/day, S = 0.00095 and Q = 25 L/s.

The result of forward analysis for 20 years of pumping was provided in **Appendix E**, which shows the drawdown in FDC03R, FDC05 and FDC01/02 is approximately 3.5 m, 2.8 m and 2.0 m, respectively.

The influence zone estimated with the Theis distance-drawdown analysis is summarised in **Table 17**, which shows the predicted drawdowns at different radiuses from the pumping well and at different time after starting of pumping.

Table 17. Influence Zones (Theis)

Time (Days)	90	180	365	7300
Radius (m)	Drawdown (m)	Drawdown (m)	Drawdown (m)	Drawdown (m)
14 (FDC03R)	2.648	2.781	2.917	3.492
100	1.893	2.026	2.161	2.737
230 (FDC05)	1.573	1.706	1.842	2.417
300	1.471	1.604	1.739	2.315
400	1.360	1.493	1.629	2.204
500	1.275	1.408	1.543	2.119
600	1.205	1.338	1.473	2.049
700 (FDC01/02)	1.145	1.278	1.414	1.989
800	1.094	1.227	1.363	1.938
900	1.049	1.182	1.318	1.893
1000	1.009	1.142	1.277	1.852
2000	0.744	0.876	1.011	1.586
5000	0.404	0.530	0.662	1.234

As **Table 17** shows, the pumping well is predicted to cause a drawdown of 3.5 m at FDC03R after 20 years of pumping, a drawdown of 2.4 m at FDC05 after 20 years pumping, and a drawdown of 1.9 m at FDC01 / FDC02 after 20 years pumping.

The drawdown values predicted with the two different models are generally close, indicating the soundness of the analysis.

Assuming the residual drawdown at FDC03R, FDC05 and FDC01 / FDC02 is greater than the predicted values of 3.5, 2.8 and 2.0 m, respectively, these three existing water supply wells should not be affected by the pumping of FDC03RR at a pumping rate of 25 L/s.

6. Groundwater Quality Assessment

6.1 GUDI Level Assessment

Based on the Source Protection Information Atlas, the site is located in WHPA-E with a score of 8.1, indicating the existing supply well (FDC03R) and any new supply wells (FDC03RR) at the site are considered to be GUDI wells. To assess the degree that the raw groundwater from the pumping well has been affected by surface water (or GUDI conditions), the City of Hamilton dictated the following groundwater sampling (**Table 5**) that can help assess GUDI conditions:

- Four sampling events for ODWQS for pumping well (FDC03RR);
- Two sampling events for ODWQS for the existing supply well (FDC03R) and sentry wells (CM-03-03-S and CM-03-03-D);
- Two Pharmaceutical samples from FDC03RR;
- Three MPA samples from FDC03RR;
- Three F-coliphage samples from FDC03RR;
- In-Situ Ultraviolet Transmission Measurement during all sampling events for FDC03RR and observation wells; and
- One Oxygen-18 and Deuterium sample from FDC03RR and FDC03R.

ODWQS Sampling:
Significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to meteorological, or surface water conditions may indicate that the groundwater is under the direct influence of surface water. Drastic fluctuations of chemical parameter values during the pumping test may indicate that recharge of the groundwater from the source of surface water occurred as the pumping might have stressed the aquifer and induced recharges. As the testing results (**Table 7**) of the multiple sampling events show, the concentration of major constituents of water samples does not fluctuate significantly, which is an indicator that the groundwater had not receive surface water recharge during the pumping test.

Pharmaceutical Sampling:
As mentioned above (section 4.2), occurrence of pharmaceutical compounds is found to be strongly correlated with the presence of modern water and with occurrence of other anthropogenic compounds. The testing results for the two samples from the pumping well show that the concentration of caffeine is less than 0.5 µg/L (minimum detection limit), which is very low, suggesting that the groundwater does not have a significant surface water source.

Microscopic Particulate Analysis (MPA):
As mentioned above, MPA is intended to identify organisms that occur only in surface waters and whose presence in groundwater clearly indicates that at least some surface water has been mixed with groundwater. The United States' Environmental Protection Agency (US EPA) Consensus Method for Determining Groundwaters Under the Direct Influence of Surface Water Using MPA describes indicators as either primary bio-indicators or secondary bio-indicators. The primary bio-indicators include Giardia, Coccidia, Diatoms, green and blue-green algae (Cyanobacteria), Insects/Larvae, Rotifers and plant debris; while the secondary bio-indicators include Nematodes, Crustaceans, Amoebae, non-photosynthetic

flagellates and ciliates, photosynthetic flagellates and iron bacteria. The Consensus Method ranked the risk levels for primary bio-indicators in **Table 18** based on particulate counts per 379 litres (100 gallon) of water sample.

Table 18. Particulate Counts for Primary Bio-Indicators and Risk Levels

Primary Bio-Indicators	EH	H	M	R	NS	Test Result
Giardia	>30	16 to 30	6 to 15	1 to 5	<1	Nil
Coccidia	>30	16 to 30	6 to 15	1 to 5	<1	Nil
Diatoms	>150	41 to 149	11 to 40	1 to 10	<1	Nil
Other Algae	>300	96 to 299	21 to 95	1 to 20	<1	Nil
Insects/Larvae	>100	31 to 99	16 to 30	1 to 15	<1	Nil
Rotifers	>150	61 to 149	21 to 60	1 to 20	<1	Nil
Plant Debris	>200	71 to 200	26 to 70	1 to 25	<1	Nil

EH – Extremely High, H – Heavy, M – Moderate, R – Rare, NS – Not Significant

MPA analysis results (**Table 9**) for the three samples did not identified existence of any primary bio-indicators, but only identified pollen and eggs of Nematodes. Based on the Consensus Method, pollen is everywhere both airborne and in water, therefore the presence of pollen grains in groundwater is of little significance. Nematodes is one of the secondary bio-indicators, therefore the identification of eggs of Nematodes is not indicative of a water quality risk. Consequently, the presence of pollen and eggs of Nematodes indicates that the groundwater from the the pumping well (FDC03RR) does not have a significant surface water source.

F-Coliphage Sampling:

In order to assess the impact of fecal contamination and gain insights into GUDI conditions of the pumping well (FDC03RR), three groundwater sampling events for F-Coliphage were conducted at 24, 48 and 72 hours respectively of pumping. Testing results (**Table 10**) show that no F-coliphage was identified in the water samples, indicating that the groundwater from the pumping well (FDC03RR) was not impacted by fecal contamination transported by surface water, which indicates that the groundwater does not have a significant surface water source.

In-Situ Ultraviolet Transmission Measurement:

Multiple UVT measurements for the pumping wells (FDC03RR) and two phases of measurements for the existing supply well (FDC03R) and the observation wells (CM-03-03-S and CM-03-03-D) were conducted to get insight into water quality and GUDI conditions. The measurement results (**Table 11**) show that the measured values for both the pumping well (FDC03RR) and the existing supply well (FDC03R) are 100% for all monitoring occasions, indicating high water quality and no variation over the time of pumping. Monitored values for the two observations wells (CM-03-03-S and CM-03-03-D) are lower than 100% due to turbidity, however do not show substantial variation. Consequently, this indicates that the groundwater does not have a significant surface water source.

Oxygen-18 and Deuterium Sampling:

Dating groundwater provides an indirect indication of GUDI conditions. Based on the analysis results (**Table 12** and **Figure 5**), groundwater from the pumping well (FDC03RR) and existing supply well (FDC03R) are recharged by local precipitation. Therefore, the groundwater quality will be a function of precipitation water quality, contaminants that the precipitation water dissolved and transported with it, and the attenuation of contaminants in vadose zone.

Based on the above assessment, the groundwater from the redundant well has not significantly mixed with a surface water source.

The above assessment suggests that the groundwater from the pumping well (FDC03RR) and the existing supply well (FDC03R) does not have a significant surface water influence.

6.2 Drinking Water Quality Assessment

Groundwater quality was observed during well construction, well development, and sampling, and no visual and or olfactory signs of contamination were identified.

Most results of groundwater sampling and testing (**Appendix C**) completed as required by the City's Groundwater Sampling and In-Situ Monitoring Program (**Table 5**) provided information about the drinking water quality. Based on the chemical testing results, the drinking water quality of the groundwater from the pumping well (FDC03RR), the existing supply well (FDC03R) and the deep observation well (CM-03-03-D) can be summarized as follows:

- No exceedance over ODWQS was identified for all water samples from the pumping well (FDC03RR) and the existing supply well (FDC03R) except for sodium, which exceeded reporting criteria (20 mg/L). The elevated sodium may be derived from either a natural bedrock source or from road salt applications.

- No exceedance over ODWQS was identified for all water samples from the two monitoring wells except for sodium and Total Coliform. The sodium concentrations exceeded reporting criteria (20 mg/L) for both monitoring wells with values for the deeper wells being much lower than the value for the shallow well. This may suggest a road salt source for the elevated sodium concentrations.

- Pharmaceutical, caffeine, is under minimum detection limits, suggesting that the groundwater does not have a significant surface water source, and the groundwater quality has not been impacted significantly by caffeine released into the environment by humans.

- Only two types of organic particulates (pollen and eggs of Nematodes) were identified and both have low counts, indicating the groundwater from the pumping well (FDC03RR) does not have a significant surface water source and has a low potential to have been contaminated by the contaminants transported by surface water.

- No F-coliphage was identified for all water samples, indicating that the groundwater from the pumping well (FDC03RR) was not impacted by fecal contamination transported by surface water.

- In-situ ultraviolet transmission monitoring for all water samples from the pumping well (FDC03RR) and the existing supply well (FDC03R) showed 100% UVT values, indicating high water quality and no variation over the time of pumping.

Based on the above assessment, the groundwater from the pumping well (FDC03RR) meets the ODWQS with the exception of sodium, and does not have a significant surface water source. The sodium exceedance over the the reporting criteria (20 mg/L) is common for the raw groundwater in the area, and may be attributed to natural bedrock chemistry or historical road salt applications.

7. Summary and Recommendations

Carlisle Well FDC03RR was constructed to provide a redundant source of water for the community of Carlisle. It is expected that FDC03RR will be used as a backup well of the existing water supply well FDC03R. The well was constructed in accordance with Ontario Regulation (O. Reg.) 903 and its associated provincial manual, Water Supply Wells – Requirements and Best Management Practices.

A step test and a 72-hour pumping test were completed for FDC03RR in accordance with O.Reg 903, the Practical Guidelines for Test Pumping in Water Wells (ICRC) and the Guide to Conducting Well Pumping Test. The well and aquifer assessment based on the data recorded from the step test and 72-hour pumping test concluded that:

- Specific well capacity ranges from 14.5 to 21.4 m^3/hr/m (348 to 513.6 m^3/day/m);
- Well loss analysis and well efficiency analysis show the constructed well is efficient;
- The aquifer is a confined aquifer with weak leaking from overlying overburden;
- No hydraulic boundary was encountered during the 72-hour pumping test;
- Transmissivity (average T value) of the aquifer is 895 m^2/day (0.01035 m^2/s);
- Storativity (average S value) of the aquifer is 0.00095;
- Sustainable yield estimates ranges from 29 to 69 L/s, averaged at 49 L/s; and
- No aquifer mining was observed during pumping test.

A comprehensive sampling program was undertaken and included analytical testing for assessment of both raw groundwater drinking quality and GUDI conditions. Samples were taken from FDC03RR, FDC03R and observation wells multiple times during the 72-hour pumping test to assess spatial variation of water quality as well as quality fluctuation over time. Sampling was conducted in general accordance with the guidelines of Practices for the Collection and Handling of Drinking Water Samples of Ontario (2009) and Palmer's groundwater sample protocols. Analysis testing was completed by the City of Hamilton's accredited environmental lab. Based on the testing results, it was concluded that:

- The groundwater from FDC03RR does not have a significant surface water source, and groundwater quality has not been significantly impacted by contamination associated with surface water;

- The raw groundwater from FDC03RR met ODWQS standards except that it exceeds the reporting criteria of sodium; and

- The existing supply well, FDC03R was designated as a GUDI well based on MECP GUDI Terms of Reference. The redundant well, FDC03RR, is only 14 m from the FDC03R and has almost the same depth. Chemical analysis results show that these two wells have similar water quality. Therefore, FDC03RR should have the same level of GUDI as FDC03R, and the existing treatment of Carlisle Drinking Water System should be enough for treating water from FDC03RR.

Based on the assessment of FDC03RR, the following recommendations are provided:

- This report and associated documents may serve as baseline condition for assessing FDC03RR and aquifer performance in the future, and these documents should accompany the well for its service life;

- Caliper logging, image logging, video inspection, flow distribution profiling, etc. should be considered before commissioning of the well to characterize the open bedrock zone and to confirm the construction quality of the well structure. These results would also serve as baseline conditions of the well;

- FDC03RR is about 14 m away from existing supply well FDC03R, and is surrounded by the WHPA-E of FDC03R which is a GUDI well based on the 2017 Technical Rules under the Clean Water Act. Based on the results of raw water sampling program as presented above, no significant impact from contaminants associated with surface water was identified, and the GUDI status of FDC03RR and FDC03R should be re-evaluated as part of WHPA update. The re-evaluation should be based on further investigation, monitoring and modelling, which may include:

    - Spike boreholes should be drilled on strategic locations of the current WHPA-E to further delineate hydrostratigraphic structures.

    - The spike boreholes will be installed with high quality monitoring wells which will be combined with existing sentry wells. GUDI parameters (**Table 5**) should be considered for groundwater sampling and testing in addition to parameters adopted currently. As part of GUDI re-evaluation, one to multiple rounds of synchronized samplings should be considered.

    - Numerical modeling should be conducted based on revised layers and updated monitoring results. The modeling results will used to update GUDI status and WPHAs. Both flow modeling and mass transport modeling should be considered.

- After the re-evaluation of GUDI, if FDC03RR and FDC03R are not found to be GUDI wells, the groundwater monitoring program can be scaled back, and monitoring frequency can be reduced. Palmer is happy to assist in reviewing the groundwater monitoring program; and

- It should be noted that the water supply is governed by O. Reg. 170/03. The City of Hamilton should treat water to ODWS before distributing it for drinking.

8. Certification

This report was prepared, reviewed and approved by the undersigned. In the acknowledgement of the practice of geoscience in Ontario, this report was prepared partly by Lauren Bourke, M.Env. Sc. Lauren is no longer with Palmer.

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Appendix A

Well Logs for Pumping Well and Observation Wells

(FDC03RR – Palmer 2023)

(FDC03R – Stantec 2004)

(CM-03-03-S and CM-03-03-D – SNC 2003)

Well Log FDC03RR

PROJECT: Carlisle Redundant Well

CLIENT: R.V. Anderson Associates Limited

PROJECT LOCATION: 84 Acredale Drive Carlisle, ON

DATUM: Geodetic

BH LOCATION:

Method: Cased rotary-percussion drilling

Diameter: 400 mm

Date: Apr-17-2023 to Apr-20-2023

REF. NO.: 2108704

ENCL NO.:

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION
273.0	Ground Surface						
0.0	**FILL:** sandy gravel to gravelly sand, trace clay, subrounded dolostone and sandstone gravel (<30 mm), brown, wet to moist, no stain and no odor. a few rootlets and anthropogenic debris.		1	GR			
269.2			2	GR			
3.8	**SANDY GRAVEL TO GRAVELLY SAND:** trace clay, subrounded to subangular dolostone, limestone and sandstonegravel (10 to 35 mm), brown, damp to dry at top, no stain and no odor. --- clean water was used as drilling fluid.		3	GR			
			4	GR			
			5	GR			
			6	GR			
261.9			7	GR			
11.1	**SANDY GRAVEL:** subrounded to subangular dolostone and precambrian rock gavel (<30 mm), greyish brown, no stain and no odor.		8	GR			
258.5			9	GR			
14.5	**DOLOSTONE:** fine-crystallized, slightly weathered at upper part, a few vugs and solution holes, geyish white.		10	GR			
255.5			11	GR			
17.5	**LIMESTONE:** fine-crystallized, grey. ---fractures.		12	GR			
252.4			13	GR			
20.6	**LIMESTONE and DOLOSTONE:** interlayered limestone and dolostone, fine-crystallized, Vuggy and fossiliferous locally, a few fractures, light grey. --- fractures.		14	GR			
			15	GR			
			16	GR			
	--- abundant vugs and fossils (25 to 27 mbgs).		17	GR			
			18	GR			
244.1							
28.9	**LIMESTONE:** fine-crystallized, thinly bedded, with siltstone interlayers at lower part, grey.		19	GR			
			20	GR			
240.5							
240.0	**SHALE:** calcareous shale with siltstone interlayers, greenish grey.		21	GR			
33.0	**END OF BOREHOLE**		22	GR			

Notes:
Grab samples of cuttings were taken with fine mesh strainer. Loss of fine materials is anticipated.
The well log was based on cutting classfication and records of construction.

Bentonite Seal

Cement Grout

W. L. 262.5 m
May 01, 2023

Open Hole

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%)
10 20 30

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m³)

REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

GROUNDWATER ELEVATIONS
Shallow/ Single Installation 1st 2nd Deep/Dual Installation 1st 2nd

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ε=3% Strain at Failure

Borehole No.: FDC03 R

Project: FDC03 replacement
Project No: 1609-00224
Location: Carlisle, Ontario
Ground Surface: 273.0 m AMSL
Top of Casing: 273.6 m AMSL

Well Drilling:
Contractor: DURL HOPPER LTD.
Date: 4-Mar-04
Field Investigator: R.Freymond, L.Veale

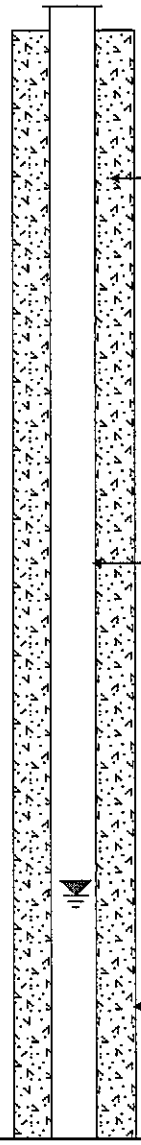
Video Inspection
Contractor : OWWS
Date of inspection: 8-Mar-04
Observed By: L.Veale

SUBSURFACE PROFILE

Depth	Depth	Lithologic Symbol	Lithologic Description	Elevation
	0.00			273.00
			SAND AND GRAVEL some boulders	
	3.40			269.60
			SILTY SAND some gravel	

WELL DETAILS

Well



stick-up 0.60 m

St.Mary's portland cement
with bentonite
total volume 523 L
density 1.54 kg/L

ASTM A53, Grade B
steel casing with threaded
couplings
ID 208 mm
wall thickness 5.6 mm

Static Water Level at
8.92 m BGS
on 8-Mar-04

285 mm diameter
borehole within overburden

Casing interval: 0.6 m AGS to 17.8 m BGS
Open hole: 17.8 m BGS to 32.9 m
Cemented: 0 m BGS to 17.8 m BGS

Drawn By/Checked By: OR/LV

Notes:
mBGS - metres below ground surface

Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario
N2H 6M7

Borehole No.: FDC03 R

Project: FDC03 replacement
Project No: 1609-00224
Location: Carlisle, Ontario
Ground Surface: 273.0 m AMSL
Top of Casing: 273.6 m AMSL

Well Drilling:
Contractor: DURL HOPPER LTD.
Date: 4-Mar-04
Field Investigator: R.Freymond, L.Veale

Video Inspection
Contractor : OWWS
Date of inspection: 8-Mar-04
Observed By: L.Veale

SUBSURFACE PROFILE					WELL DETAILS
Depth	Depth	Lithologic Symbol	Lithologic Description	Elevation	Well
38					
39					
40	12				
41					
42					
43	13				
44					
45					
46	14	14.00	SANDY SILT(HARDPAN) some coarse gravel and boulders, brown, very dense	259.00	
47					
48					
49	15	15.20	BEDROCK dolostone, light brownish grey	257.80	
50					
51					
52			highly weathered to 16.5 m, fossiliferous with vuggy porosity to 23 m becoming heavily fractured from 23 m to 27.5 m		
53	16				
54					
55					
56	17				
57					
58			17.8 m - casing tightly set into bedrock, cement seal visible		
59	18				200 mm diameter borehole within bedrock
60			18.5 to 20 m - vuggy porosity		
61					
62	19				
63					
64					
65					
66	20		20.5 to 23 m - vuggy porosity increasing in size and percentage		
67					
68			20.7 m - fracture		
69	21				
70			21.4 m - fracture		
71					
72	22				
73					
74			22.6 m - fracture		
75					
76	23				
77					

Casing interval: 0.6 m AGS to 17.8 m BGS
Open hole: 17.8 m BGS to 32.9 m
Cemented: 0 m BGS to 17.8 m BGS

Drawn By/Checked By: OR/LV

Notes:
mBGS - metres below ground surface

Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario
N2H 6M7

Borehole No.: FDC03 R

Project: FDC03 replacement
Project No: 1609-00224
Location: Carlisle, Ontario
Ground Surface: 273.0 m AMSL
Top of Casing: 273.6 m AMSL

Well Drilling:
Contractor: DURL HOPPER LTD.
Date: 4-Mar-04
Field Investigator: R.Freymond, L.Veale

Video Inspection
Contractor : OWWS
Date of inspection: 8-Mar-04
Observed By: L.Veale

SUBSURFACE PROFILE | WELL DETAILS

Depth	Depth	Lithologic Symbol	Lithologic Description	Elevation	Well
78					
79 — 24					
80			23 to 27.5 m significant fracture zone, high water production		
81					
82 — 25			25 to 26.5 m large cavern present with in heavily fractured zone from 25 to 26.5 m		
83					
84					
85 — 26					
86					
87					
88					
89 — 27					
90					
91					
92 — 28			large fracture zone from 28.6 to 28.8 m - some water production		
93					
94			fracture 28.9 m - some water production		
95 — 29			green shale layers below 29.6 m		
96			large fracture zone from 29.4 to 29.65 m - some water production		
97					
98 — 30			large fracture zone from 30.15 to 30.4 m - some water production		
99					
100			large fracture zone from 30.6 to 30.95 m - some water production		
101					
102 — 31			fracture 31.2 m - some water production		
103					
104					
105 — 32					
106	32.60			240.40	
107	32.92		BEDROCK green shale	240.08	
108 — 33					bottom of borehole 32.9 m
109					
110					
111					
112 — 34					
113					
114					
115 — 35					
116					
117					

Casing interval: 0.6 m AGS to 17.8 m BGS
Open hole: 17.8 m BGS to 32.9 m
Cemented: 0 m BGS to 17.8 m BGS

Notes:
mBGS - metres below ground surface

Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario
N2H 6M7

Drawn By/Checked By: OR/LV

CM-03-03d

BOREHOLE LOG

Logged By:	Reviewed By	Sheet Number:	Test Pit Number:
H. Sangam	Draft	1 of 2	CM-03-03

Drilling Company:	Drilling Equipment:	Drilling Method:	Start Date:	End Date:
Lantech Drilling Services	CME-75	SSA and HQ-Core	27 Mar 03	28 Mar 03

Final Hole Depth (m):	Final Well Depth (m):	Hole Diameter (m):	Well Diameter (m):	Pipe Stickup (m):
27.4	27.37	0.1	0.1	0.50

Ground Elevation (m):	TOC Elevation (m):	Depth to Water BTOC (m):	Depth to Water BGS (m):	Groundwater Elevation (m):
n.a.	Not Surveyed	5.60	5.10	n.a.

Sample Type Legend:

SS Split Spoon Sample; AU Auger Sample
PS Pionjar Sample; VA Vane Test Interval
GR Grab Sample; SP Standard Penetration Test
RX Core Sample; SH Shelby Tube Sample

Borehole Location Description/Notes:

Northing: 4808434
Easting: 563016 Zone 17T

Sample Type, No., and Interval	Blow Counts (blows/6 cm)	N-Value	Sample Recovery	Elevation (m) / Depth (m)	Depth Scale (m)	Material	Stratigraphic Description	Well Materials	Well Construction Details
SS-1		n.a.		0.10	1		TOPSOIL-FILL Brown, some gravel and clay		Backfill
SS-2		n.a.		3.05	4		Brown, layered, some gravel		
SS-3		n.a.		5.79	6		Brown, layered, some clay, damp		
RX-4		n.a.		5.94	7		BOULDER -White grey -Water intermitently turning brown and milky white -granite at about 6.24 m to 6.47 m		Bentonite Seal 0.20 m Steel Casing
RX-5		n.a.			8				
RX-6		n.a.			9				
RX-7		n.a.		9.19	10		-Fractured with with occasional -brown soil material in fractures (washed out) by drilling fluid		
RX-8		n.a.		10.97	11		BEDROCK - DOLOSTONE -grey -fractures at about every 0.15 m		
RX-9		n.a.			12				
RX-10		n.a.		12.19			-completely fractured -gravel like cuttings		
RX-11		n.a.		12.95	13		-open fractures -filling soil washed out -highly fractured -gravel like cuttings		
RX-12		n.a.		13.44					
RX-13		n.a.		13.67	14		-fractures with filing soil wash out -dissolution cavities		

SNC-LAVALIN
Engineers & Constructors

Project Name: Hamilton Groundwater Study
Project Location: Ontario

Project Number: 331256

TEST-PIT-NEW CIRCLE.GPJ HAMILTON.GDT 4/8/03

BOREHOLE LOG

Logged By:	Reviewed By:	Sheet Number:	Test Pit Number:
H. Sangam	Draft	2 of 2	CM-03-03

Sample Type Legend:

SS Split Spoon Sample
PS Piezjer Sample
GR Grab Sample
RX Core Sample
AU Auger Sample
VA Vane Test Interval
SP Standard Penetration Test
SH Shelby Tube Sample

Borehole Location Description/Notes:

Northing: 4806434
Easting: 583016 Zone 17T

Sample Type, No., and Interval	Blow Counts (#/0.5 cm)	N-Value	Sample Recovery	Elevation (m) / Depth (m)	Depth Scale (m)	Material	Stratigraphic Description	Well Materials	Well Construction Details
				15.24	16		-fractured, open fractures -abundant dissolution cavities		
RX-1		n.a.							
				17.22	17		-highly fractured -angular gravel like cuttings		
RX-1		n.a.			18				
				18.57	19		-micropores -rough core		
RX-1		n.a.		19.76	20		-highly fractured -gravel like cuttings		0.10 m Diameter Open Hole from 13.72 mbgs to 27.37 mbgs
RX-1		n.a.		21.13	21		-micropores -rough core surface		
RX-1		n.a.		22.60	22		-Intact rock, no factures -smooth core surface		
RX-1		n.a.			23				
RX-1		n.a.			24				
				24.33			SHALE -dark grey, very stiff -plastic clay seams starting at about 25.5 mbgs -clay seams at every 0.1 to 0.20 m -becoming greenish with depth		
RX-2		n.a.			25				
RX-2		n.a.			26				
					27				
				27.37			End of Borehole		

SNC-LAVALIN
Engineers & Constructors

Project Name: Hamilton Groundwater Study
Project Location: Carlisle

Project Number: 331256

TEST-PIT-NEW CARLISLE.GPJ FASHDWA1.GDT 8/8/03

Appendix B

Pumping Test Design Report Notification Letter

(Palmer 2023)

871 Equestrian Court, Oakville, Unit 1, ON L6L 6L7
Tel: 647-795-8153 | www.pecg.ca

April 6, 2023

To: Andrew McGregor
R.V. ANDERSON ASSOCIATES LIMITED
(905) 685-5049 x4211
amcgregor@rvanderson.com

CC: City of Hamilton
Ahmad Sarwar, P.Geo.
Ahmad.Sarwar@hamilton.ca

From: Frank C. Liu, P.Eng. & Lauren Bourke, M.Sc., G.I.T.

Cc: Jason Cole, M.Sc., P.Geo.

Re: **Pumping Test Design Report – Redundant Well of Carlisle Well Field, ON**

1. Introduction

Palmer has prepared this Pumping Test Design Report on behalf of R.V. Anderson and Associated (RVA) and the City of Hamilton to support a registration on the Ministry of the Environment, Conservation and Parks (MECP) Environmental Activity and Sector Registry (EASR) for a non-reoccurring pumping test with a duration of less than 7-days for a volume less than 5,000,000 L/day. The proposed pumping test is a 72-hour pumping test to confirm the hydraulic properties and yield of a proposed redundant well (FDC03RR) to be built and added to the existing Carlisle well site of well FDC03R located at 84 Acredale Road, Carlisle, ON. This project is being completed as part of the Carlisle Water Storage Facility Municipal Class Environmental Assessment (EA) being led by RVA.

The report will serve as a directory document for executing the pumping test and will provide information for assessing well performance and aquifer properties.

1.1 Test Well Information

The proposed redundant well (FDC03RR) is located at northeast corner of Carlisle with a municipal address of 84 Acredale Road, Carlisle (**Figure 1**). **Table 1** lists the details of the proposed redundant well, with details provided from the existing well, FDC03R, located on site.

Table 1. Proposed Redundant Well Details

Well ID	FDC03RR
Well Address	84 Acredale Road, Carlisle, ON
Expected Date of Construction	April 17, 2023
Well Tag	NA
Casing Material	Steel
Casing Diameter	8”
Casing Depth	0-19 mbgs*
Bedrock Open Hole	19-32 mbgs
Total Depth of Well	32 m
Water Producing Zone	19-30 m (bedding fissures, vugs and fractures of Armabel/Gasport FM)
Static Groundwater Level	9.2 mbgs

***mbgs-meters bellow ground surface**

2. Pumping Test Description

Pumping tests include a step-drawdown test and a constant rate pumping test. The details of pumping tests are presented in **Table 2**.

Table 2. Pumping Test Details

Test Information	Description
Step-Drawdown Test	Four steps: 1st step of 6.3 L/s for one hour or less, 2nd step of 12.5 L/s for one hour or less, 3rd step of 18.8 L/s for one hour or less and 4th step of 25 L/s for one hour or less. Recovery to at least 80% prior to start of the constant rate test.
Constant Rate Test	Constant rate of 25 L/s for 72 hours
Recovery Test	Keep monitoring groundwater levels until 90% recovery
Purpose of Test	Evaluate the capacity of the redundant well (well performance) and aquifer properties.
Maximum Daily Water Taking	2,160,000 L
Pumping Test Being Completed By	Highland Well Drilling under the supervision of Frank Liu, P.Eng. and Jason Cole, P.Geo.

Before the start of the pumping test, the pumping for the existing well FDC03R will be stopped after the existing water tower has been filled and other municipal wells have been confirmed to be in operable condition to avoid turbidity and other particulate materials produced by drilling from entering the FDC03R. The well pump and equipment in existing Municipal Well FDC03R will be removed and the well will be taken

offline for the entire duration of the well drilling and pumping test. Packers will be installed in the municipal well FDC03R, which will include an approx. 2" opening to allow for installation of a datalogger, obtain manual groundwater levels and to collect a sample using a submersible or low flow sampling device.

The permitted water taking pump rate for FDC03R is 25 L/s. Based on the pumping schedule of FDC03R, its pumping rate is typically between 17 and 18 L/s, with a drawdown of approximately 3.0 m. Therefore, recommended pumping rate for the pumping test of FDC03RR is the maximum permitted rate of 25 L/s in order to avoid unacceptable well interference and to confirm the maximum permitted yield for the redundant well. The EASR pumping rate for FDC03RR is selected as the same as the permitted rate for FDC03R.

3. Hydrogeological Conditions and Impact Assessment

3.1 Geological Setting

The site is located on the Flamborough Plain physiographic region (**Figure 2**) (Chapman & Putnam, 1984). Available surficial mapping by the Ontario Geological Survey (OGS) indicates the surficial geology is comprised of ice-contact stratified deposits of sand and gravel, with minor silt, clay and till (Error! Reference s ource not found.) (OGS, 2003).

Bedrock in this area is characterized by dolostone from the Lower Silurian of Armabel Formation, which is a tan coloured dolostone (**Figure 4**). This unit is thick-bedded crinodial, locally biohermal and bituminous dolostone (OGS, 1991).

3.2 Source Water Protection

The site is located within the Halton Region Source Water Protection Area (**Figure 5**). It is located within a Wellhead Protection A with a score of 10 in a Wellhead Protection area with Groundwater Under Direct Influence (WHPA-E) with a score of 8.1. The site is also designated as a significant groundwater recharge area (SGRA). The west site boundary is also located approximately 350 metres from a highly vulnerable aquifer (HVA) with a score of 6 (**Figure 5**).

The redundant well will be completed in bedrock open hole similar to FDC03R and the monitoring program will include evaluating the water level response to pumping at the redundant well.

3.3 Surface Water Features

The redundant well is located approximately 140 m east of a watercourse (West Creek) and 190 m west of a watercourse (East Creek). Both West Creek and East Creek are tributaries to the Bronte Creek. Located approximately 150 metres northeast of the site, is the Pogreston North Swamp, while the Carlisle North Forests are located to the northwest of the site, which is associated with the tributaries of the Bronte Creek. During previous testing, no response was seen in the overburden beneath the West Creek, indicating that no impact to baseflow or water levels in this area are to be expected (Stantec, 2004).

Water from the pumping test will be discharged into the catch basin of a storm pipe located at the northeast quadrant between Acredale Drive and Blackberry Place (**Figure 1**). The storm pipe links to the culvert that crosses the Blackberry Place and opens to the West Creek. The diameter of the storm pipe is greater than 70 cm. The capacity of the pipe is estimated to be well over 25 L/s based on Manning's Formula. The condition of the storm pipe should be confirmed before the pumping test.

The pumping test should be scheduled to avoid major storms in order to prevent overwhelming of the storm pipe capacity, and resultant flooding and erosion.

Well records within 200 m of the site indicate that the soils are loam and brown clay with gravel or sandy stones, approximately 0 to 6 metres deep. MECP well records close to the site indicate that bedrock of limestone is located at 15.2 mbgs, and in wells 200 metres away, limestone can be found as shallow as 5.6 metres.

Surficial geology indicates that soils within the site consist of sand and gravel with minor silt, clay and till (**Figure 3)**.

Portions of the stream condition of the West Creek will be monitored during discharge to ensure that no surface water flooding and erosion will happen. Existing wells, including FDC03R and CM-03-03S/D (**Figure 1**) located near the redundant well will be monitored during the pump test to assess well interference.

The discharge location was chosen to be located downstream and far enough from the pumping well to ensure the discharged water will not flow back to the pumping wells. The quality of the surface water will be monitored prior to commencing and following completion of the pump test, as described further in Section 5.4

3.4 Local Groundwater Use

The Carlisle Well Field is one of the five groundwater based municipal systems in Halton Region Source Protection Area, and includes four (4) active supply wells (FDC01, FDC02, FDC03R, FDC04). FCD03R is located on the same property as the proposed redundant well. FCD03R and FDC05 supply water to the community of Carlisle and are located north of Carlisle Road on Acredale Drive (FDC03R) and Oldenburg Road (FDC05) **(Figure 6**).

FDC03R is completed in dolostone bedrock with an uncased bedrock hole from approximately 17.7 m to 32.9 m (Wood, 2021). FCD03R is located on the same property as the redundant well and supplies the municipality of Carlisle (PTTW: 8228-AJZK9H). FDC03R is permitted to take 2,160,000 L/day. FDC05 is located approximately 230 metres away from the site and is also used as a groundwater supply for the municipality of Carlisle (PTTW: 4207-AJZJ4L) and is permitted to take 1,296,000 L/day. There are five (5) other PTTW sites located within 1 km of the redundant well site, all these sites are greater than 500 metres form the redundant well site. The information for each PTTW can be found in **Table 4**.

A review of the MECP water well records indicate that within a 500-metre radius of the redundant well there are 21 wells. There are 3 wells located within 200 metres of the site that are not located within the site boundary (**6**). The site boundary is referred to as the municipal property boundary of 84 Acredale Road, Carlisle, ON.

The Well records within 500 metres of the site are in **Appendix A. Table 3** show the summary of the well records.

It should be noted that MECP well records are inventoried just to get a snapshot of the regional groundwater resources information. As mentioned above, as the pumping rate for the proposed redundant well, FDC03RR, will be the same as the permitted pumping rate of FDC03R, the well interference of the pumping test to other supply wells close to the site is not expected. Therefore, monitoring of nearby supply wells are not required.

Table 3. Summary of Well Records

Classification		Record Number
Water Use	Domestic/livestock	8
	Commercial	1
	Industrial/Cooling	1
	Municipal/Public	5
	Monitoring/Observation	1
	Monitoring and Test Hole	-
	Dewatering	-
	Irrigation	1
	Decommissioned	1
	Unknown/Not in use	4
Water Quality	Fresh	10
	Salty	-
	Untested	-
	Unknown	11

It should be noted that the FDC03R will be shut down during pumping test. As the permitted pumping rate of FDC03R is equal to the pumping rate of pumping test for the proposed redundant well, the influence zone and well interference caused by the pumping test for FDC03RR will not exceed the influence zone and well interference caused by pumping of FDC03R. Therefore, no adverse interference from the pumping test with the surrounding supply wells is expected.

Table 4. PTTWs within 1 km of Site

Permit Number	Client Name	Use	Specific Purpose	Expiry Date	Issue Date	Source	Source ID	Maximum litres allowed per day	Number of days water taking allowed	Distance (m) from FDC03RR
4347-BYPPG2	City of Hamilton	Water Supply	Municipal	2031-03-01	2021-03-01	Ground Water	Carlisle Wells (FDC01)	851000	365	750
4347-BYPPG2	City of Hamilton	Water Supply	Municipal	2031-03-01	2021-03-01	Ground Water	Carlisle Wells (FDC02)	851000	365	680
6158-B24MKT	Brenda P. Kuiper and Richard M. Kuiper	Industrial	Power Production	2028-05-31	2018-06-28	Surface Water	Bronte Creek	1.73E+08	365	890
4682-AAPNBN	1372830 Ontario Inc.	Commercial	Other – Commercial	2026-02-28	2016-06-07	Surface and Ground Water	Pond 1	455000	230	930
4682-AAPNBN	1372830 Ontario Inc.	Commercial	Other – Commercial	2026-02-28	2016-06-07	Surface and Ground Water	PW1-91	501120	92	930
8228-AJZK9H	City of Hamilton	Water Supply	Municipal	2025-08-31	2017-03-07	Ground Water	Well FDC 03R	2160000	365	28
4207-AJZJ4L	City of Hamilton	Water Supply	Municipal	2025-08-31	2017-03-07	Ground Water	Well FDC05	1296000	365	230

4. Notification Protocol

Prior to the start of any pumping tests, notification will be provided to nearby residents. Notification letters will be dropped to residents close to the site who might be affected by the drilling and pumping test at least 48 hours prior to the start of the drilling and pumping test (**Figure 6**).

The notification will include:

- a description of where the taking is to occur;
- the dates on which the water is intended to be taken;
- the approximate time and duration that the water takings will occur;
- the EASR registration number; and,
- the name and telephone number of a person who can be contacted to report any concerns about interference with another water supply.

5. Monitoring Plan

Monitoring will be carried out during the daytime throughout the 72-hour test. Data loggers will be installed to monitor groundwater levels all time throughout the pumping test. The redundant well and the two existing wells, FDC03R and CN-03-03S/D, will be monitored (**Figure 1**).

5.1 Groundwater Level Monitoring for Pumping Well and Existing Wells and Pumping Rate Monitoring

Monitoring activities for groundwater levels will include:

- Monitoring the pumping rates and volumes o the redundant well using a flowmeter provided by the contractor. A measuring bucket will be used to estimate the pumping rate periodically to confirm and ensure the pumping rate is constant rate through adjusting the pump valve if needed;
- Manually monitoring water levels prior to, during and after the pumping test for the pumping wells and existing wells;
- Installing dataloggers to automatically measure water levels in both the pumping wells and the existing wells;
- Recovery monitoring will also be completed following pump shutoff including manual measurements and automatic dataloggers until at least 90% recovery is achieved.

Groundwater level monitoring for the existing wells will start prior to the shutting down the pumping of FDC03R to monitoring groundwater level fluctuations as a result of shutting down the pumping of FCC03R.

5.2 Surface Water Feature Monitoring

Surface water features such as stream flow, springs, valley walls, stream beds will be monitored through visual surveillance for signs of flooding, erosion, sedimentation and slope stability before and during pumping test. Visual surveillance area is marked on **Figure 1.** Monitoring results will be recorded through documents or time-stamped photography.

5.3 Private Well Monitoring

As the influence zone and well interference caused by the pumping test will not exceed the influence zone and well interference caused by the current pumping of FDC03R, monitoring private wells are not required. In addition, no private wells are expected within the zone of influence as the town of Carlisle is serviced by Municipal supply.

5.4 Groundwater and Surface Water Sampling

Groundwater and surface water sampling will be conducted in accordance with the requirements of the client (**Table 5**). The purposes of the groundwater and stream water sampling is to characterize groundwater quality condition and help assess the Groundwater Under the Direct Influence of Surface Water (GUDI) conditions of the redundant well. Groundwater and surface water quality samples will be collected by Palmer staff and submitted to three labs for different analysis, including:

1. City of Hamilton Lab: Sampling for Standard and Full Package under ODWQS;
2. York/Durham Lab: Crypto/Giardia/MPA Analysis and F-Colliphage; and
3. University of Waterloo Analytical Lab: Oxygen 18 and Deterium Age Dating.

It should be noted that the unnamed creek to the north of the site is intermittent, and water in the creek should be mostly or all from storm runoff. Sample bottles will be prepared and grab samples should be taken if there is enough depth of water for sampling in creek.

Table 5. Groundwater and Surface Water Sampling Plan

Monitoring Location	Prior to Starting Pumping Test	24-hour	48-hour	72-hour
New Redundant Well				
FDC03RR	ODWQS Standard Package Pharmaceutical (Caffeine) Field Monitoring (incl. UVT) (After development and step test)	ODWQS Standard Package MPA Analysis F-Colliphage Field Monitoring (incl. UVT)	ODWQS Standard Package MPA Analysis F-Colliphage Field Monitoring (incl. UVT)	ODWQS Full Package MPA Analysis Pharmaceutical (Caffeine) F-Colliphage ^{18}O and ^{2}H Age Dating Field Monitoring (incl. UVT)
Existing Municipal Well				
FDC03R	ODWQS Standard Package Field Monitoring (incl. UVT) (Before pump shutdown, removal and before drilling)	-	-	ODWQS Standard Package ^{18}O and ^{2}H Age Dating Field Monitoring (incl. UVT)
Monitoring Wells				
CM-03-03-S	ODWQS Standard Package Field Monitoring (incl. UVT) (Before drilling)	-	-	ODWQS Standard Package Field Monitoring (incl. UVT)
CM-03-03-D	ODWQS Standard Package Field Monitoring (incl. UVT) (Before drilling)	-	-	ODWQS Standard Package Field Monitoring (incl. UVT)
Surface Water Feature				

Unnamed Creek	ODWQS Standard Package Field Monitoring F-Colliphage	-	-	ODWQS Standard Package Field Monitoring Age Dating
Notes				
GUDI Analysis = MPA and F-Colliphage and field UVT Monitoring				
GUDI Samples to be collected using a sampling collector device that collects more than 1L, but not more than 1,000 L				

6. Discharge Plan

As shown on **Figure 1**, pumped water will be discharged through a discharge pipe of 15 cm diameter. The discharge pipe will be threaded through culvert pipes along Acredale Drive, and links to sink basin of a storm pipe located at the northeast quadrant between Acredale Drive and Blackberry Place. A visual culvert inspection will be completed before the pumping test to ensure that the culverts are clear of debris and will allow a pipe and/or water to pass through freely.

The storm pipe links to the culvert that crosses the Blackberry Place and opens to the West Creek. The discharge pipe is approximately 150 m long. Discharge rate is the same as the designed pumping rate of 25 L/s and will be gauged with flowmeter provided by the contractor. The daily discharge quantity will be 2,160,000 L/day. Based on the City's correspondence with Conservation Halton (CH), it has been confirmed that there will not be a requirement to obtain a permit from CH to discharge the pumped water into the naturalized area during the test.

The redundant well will be fully developed prior to the pumping test, and the discharged water will be monitored for organic contents during the pumping test using a portable UVT meter.

7. Contingency Plan

Palmer will be in regular contact with the on-site personnel and will be on-site daily during the pumping tests. Potential impacts and contingency plans are presented in **Table 6.**

Table 6: Contingency Plan for Pumping Test

Potential Adverse Impact	Contingency Plan
Unsustainable Drawdown in redundant well	Adjust pumping rates to achieve sustainable drawdown for the entirety of the test when drawdown records for the redundant well show unsustainable dropping. Reason will be investigated and documented.

Unsustainable drawdown in FDC03R or in CN-03-03s/d that may lead to shortage of water.	Adjust pumping rates in redundant well and monitor impacts from monitoring wells when drawdown records of these monitoring wells show unsustainable dropping. Reason will be investigated and documented.
Shortage of water in nearby wells from pumping test	Stop pumping test and monitor recovery in redundant well and nearby wells. Notify the MECP of shortage and provide alternate water sources to affected residents.
Adverse water quality seen in UVT meter	Alter pumping rates in redundant well and monitor impacts to surface water and discharged water.
Note: occurrence of any above adverse impacts should be advised to the city and RVA immediately.	

Signatures

This report was prepared and reviewed by the undersigned:

Prepared By:

Lauren Bourke, M.Sc., G.I.T.
Environmental Scientist

Prepared By:

Frank C. Liu, P.Eng.
Senior Hydrogeologist

Reviewed By:

Jason Cole, M.Sc., P.Geo.
VP, Principal Hydrogeologist

References

Chapman, L.J. and Putnam, D.F. 1984:
Physiography of Southern Ontario; Ontario Geological Survey.

Ontario Geological Survey (OGS). 1991:
Bedrock geology of Ontario, southern sheet. Ontario Geological Survey, Map 2544

Ontario Geological Survey (OGS). 2003:
Surficial geology of Southern Ontario.

Wood. 2021:
Below Grade Well Assessment Carlisle Municipal Wells FDC03R and FDC05.

Stantec. 2004:
Carlisle Water Supply Evaluation-Addendum Carlisle, Ontario

871 Equestrian Court, Oakville, Unit 1, ON L6L 6L7
Tel: 647-795-8153 | www.pecg.ca

Figure 1. Pumping and Discharge Plan

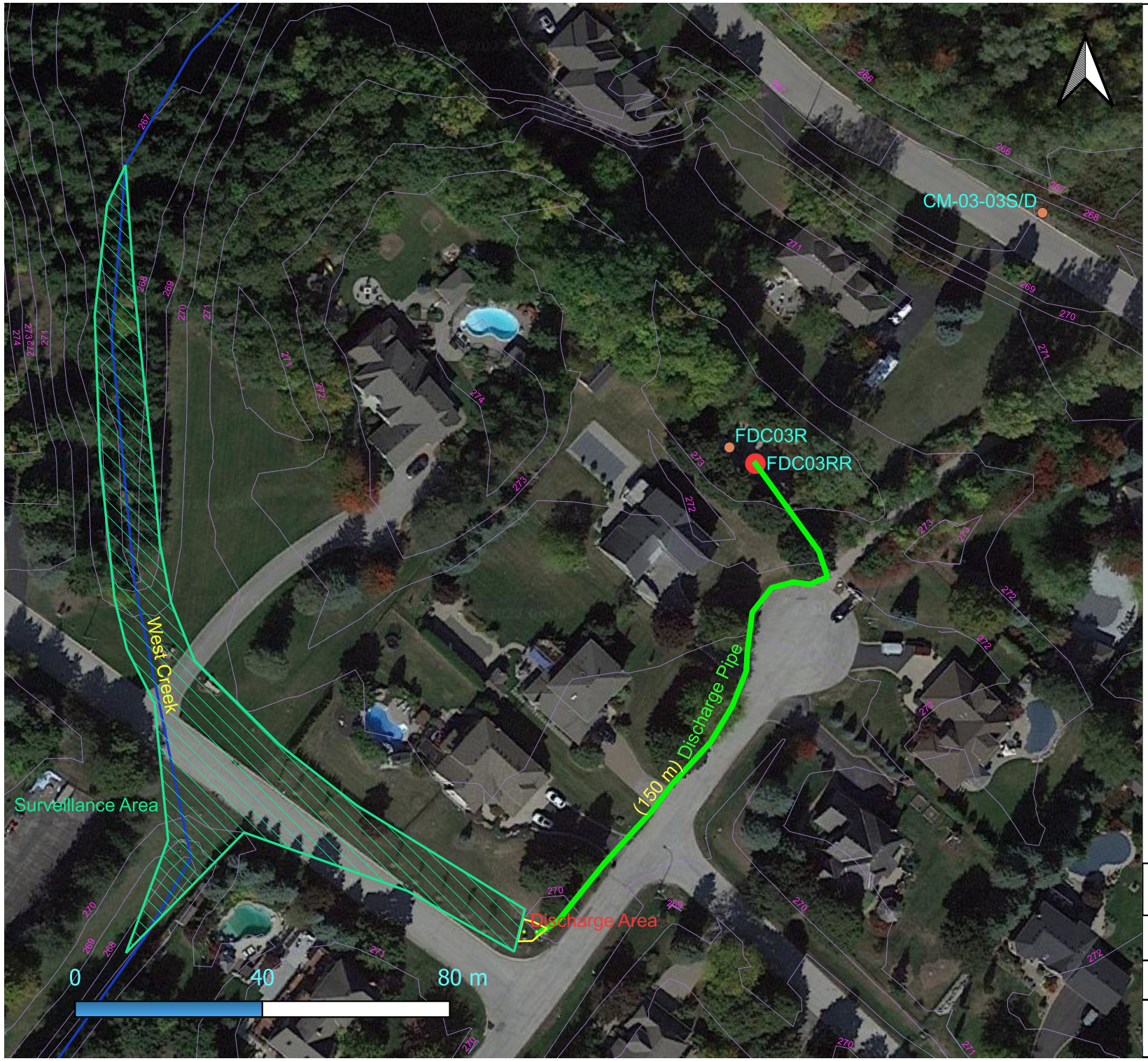
Figure 2. Physiography

Figure 3. Surficial Geology

Figure 4. Bedrock Geology

Figure 5. Source Water Protection

Figure 6. MECP Well Records



LEGEND

Municipal Wells

- Pumping Well
- Monitoring Well
- Discharge Pipe
- Discharge Area
- Stream Surveillance
- Water Course
- Top Contours (1 m)

Step Test:

L/s	Hour
6.3	1
12.5	1
18.8	1
25	1

Constant Rate Test:

25L/s (396 gpm for 72 hours)

Discharge area was blankded with strew mat to prevent erosion if needed.

Stream surveillance for signs of flooding and erosion.

GW sampling according to sampling plan of Hamilton.

CLIENT
R.V. ANDERSON ASSOCIATES LIMITED

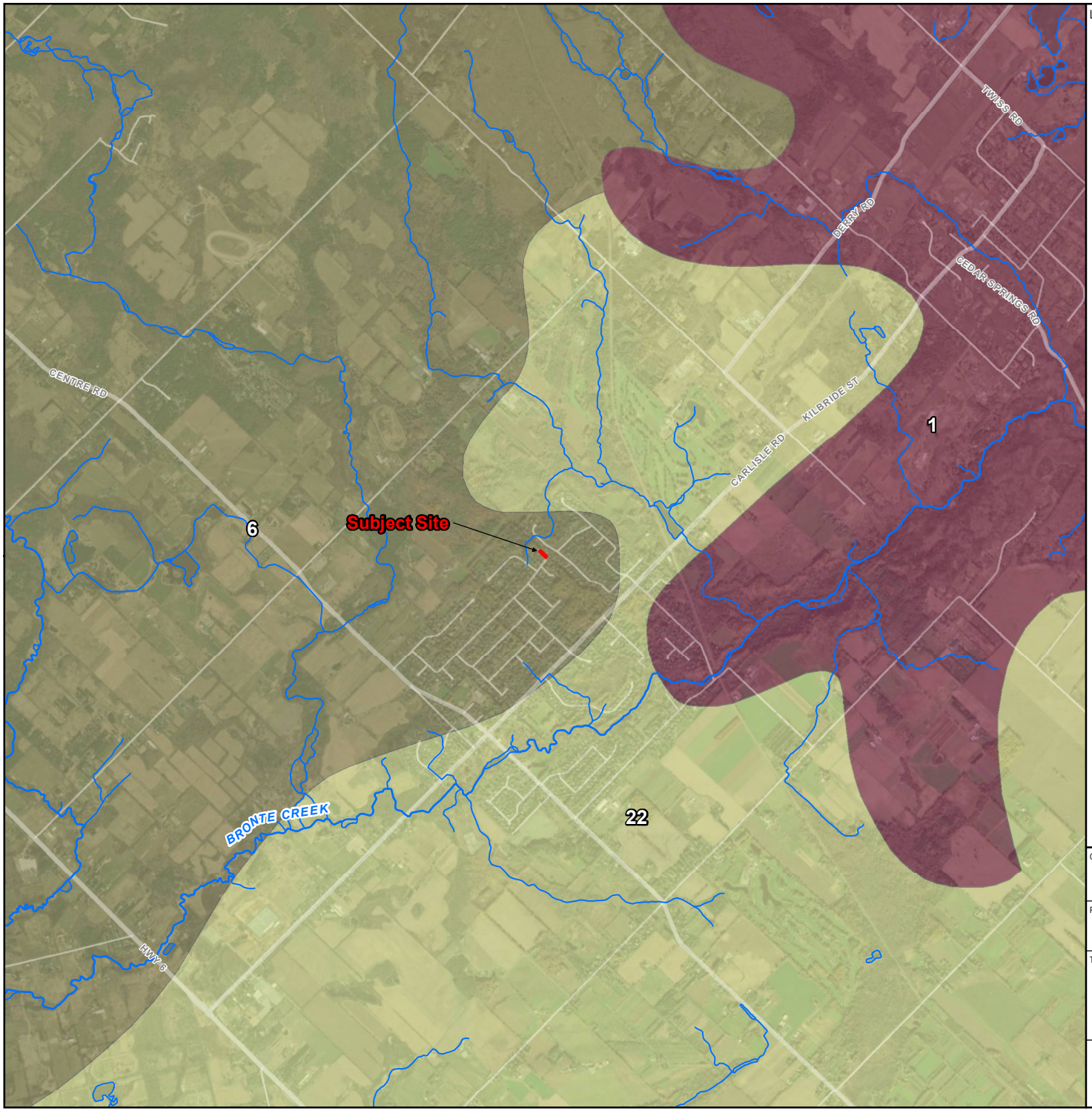
PROJECT
Carlisle Well Field, Hamilton, Ontario

TITLE
Pumping and Dishcarge Plan

Palmer™

REF. NO: 2108704

Figure 1



LEGEND

Subject Site

Watercourse[1]

Physiographic Region[2]

1: Niagara Escarpment

6: Flamborough Plain

22: Norfolk Sand Plain

1. LIO/MNRF
2. Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228

0 200 400 800 1,200 1,600 2,000

METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:40,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

Source Notes:
Imagery (2021) provided by Esri basemap service.
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CLIENT

R.V. Anderson Associates

PROJECT

Carlisle Water Storage EA

TITLE

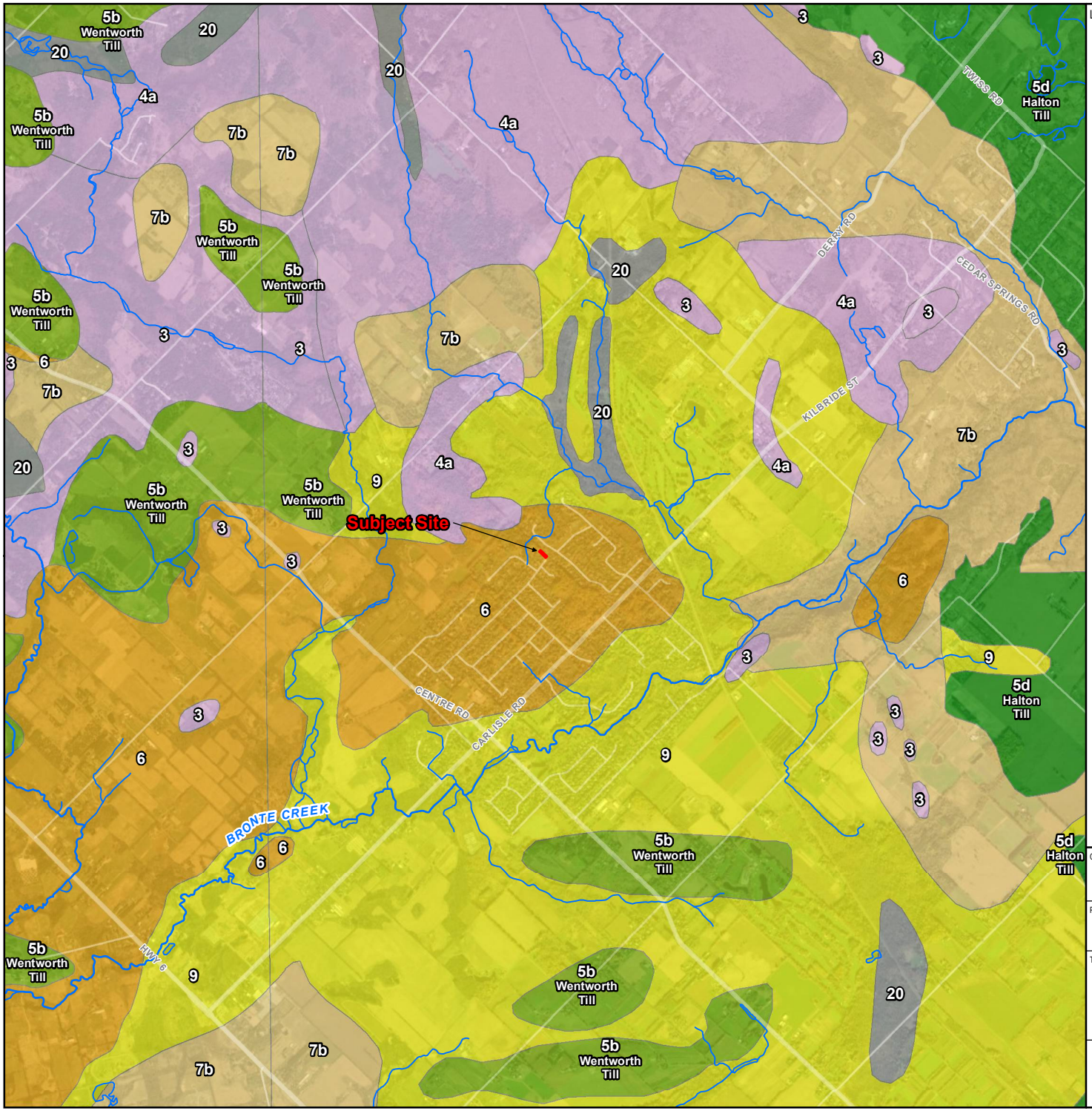
Physiography

Palmer™

REF. NO. 2108704-1-1

Figure 2

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-1-1-Physiography.mxd



LEGEND

Subject Site

Watercourse[1]

Surficial Geology[2]

Phanerozoic / Cenozoic / Quaternary / Recent

20: Organic deposits *(peat, muck, marl)*

Phanerozoic / Cenozoic / Quaternary / Pleistocene

9: Coarse-textured glaciolacustrine deposits *(sand, gravel, minor silt and clay)*

7b: Glaciofluvial deposits *(Gravelly deposits)*

6: Ice-contact stratified deposits *(sand and gravel, minor silt, clay and till)*

5b: TillI *(Stone-poor, sandy silt to silty sand-textured till on Paleozoic terrain)*

5d: TillI *(Clay to silt-textured till [derived from glaciolacustrine deposits or shale])*

Phanerozoic / Paleozoic

4a: Bedrock-drift complex in Paleozoic terrain *(Primarily till cover)*

3: Paleozoic bedrock

1. LIO/MNRF
2. Ontario Geological Survey 2010 (Mapped at 1:50,000). Surficial geology of southern Ontario; Ontario Geological Survey. Miscellaneous Release- Data

0 200 400 800 1,200 1,600 2,000

METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:40,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

Source Notes:
Imagery (2021) provided by Esri basemap service.
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CLIENT
R.V. Anderson Associates

PROJECT
Carlisle Water Storage EA

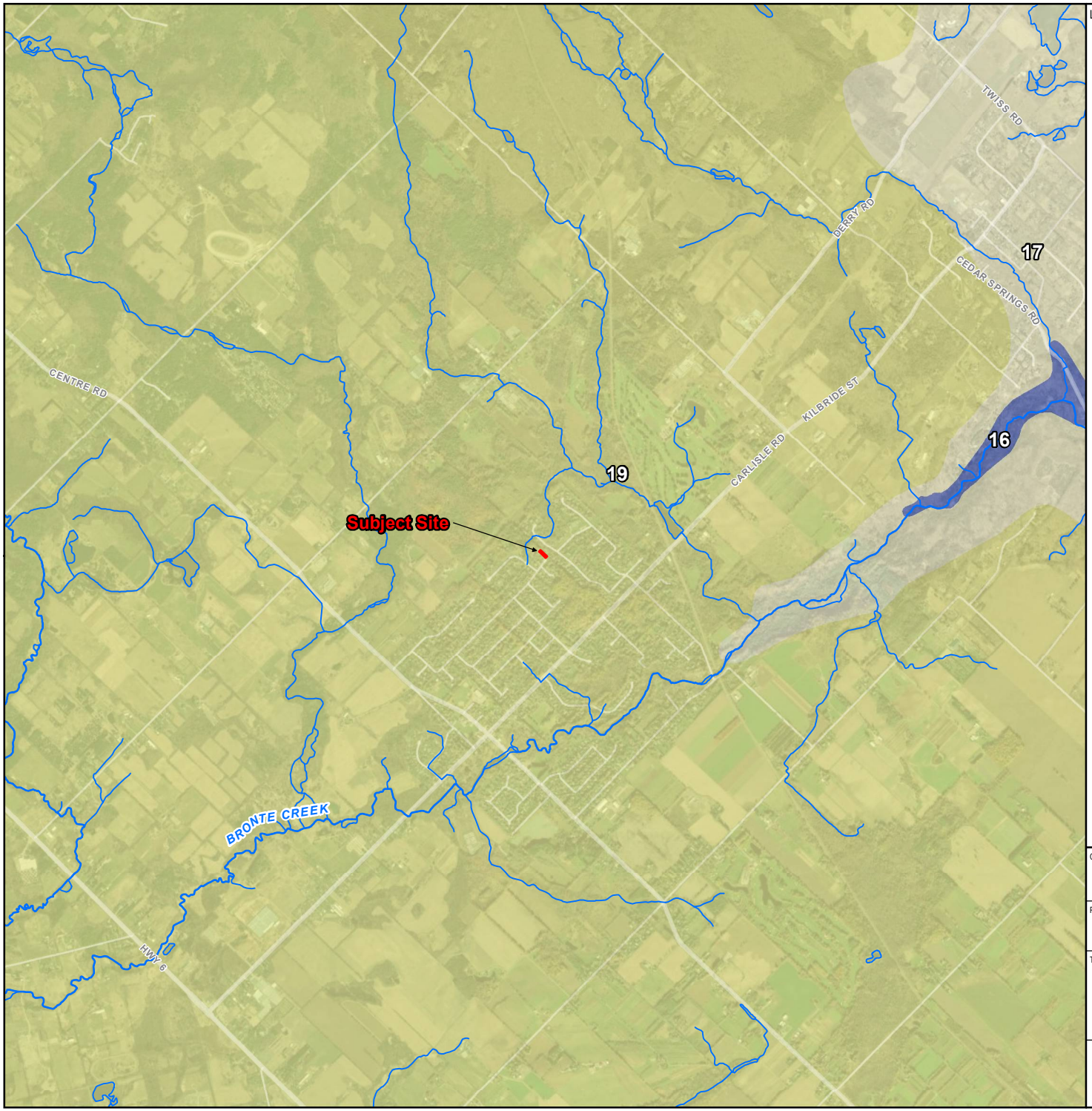
TITLE
Surficial Geology

Palmer™

REF. NO. 2108704-2-1

Figure 3

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-2-1-Surficial Geology.mxd



LEGEND

Subject Site

Watercourse[1]

Paleozoic Bedrock Geology[2]

Lower Silurian

19: Amabel *(dolostone; thick-bedded, crinoidal, locally biohermal; includes bituminous dolostone)*

17: Clinton-Cataract Group *(shale, sandstone, dolostone, limestone units)*

Upper Ordovician

16: Queenston *(shale, siltstone, minor limestone and sandstone)*

1. LIO/MNRF
2. Armstrong, D.K. and Dodge, J.E.P. Paleozoic Geology Map of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 219

0 200 400 800 1,200 1,600 2,000
METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:40,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

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CLIENT
R.V. Anderson Associates

PROJECT
Carlisle Water Storage EA

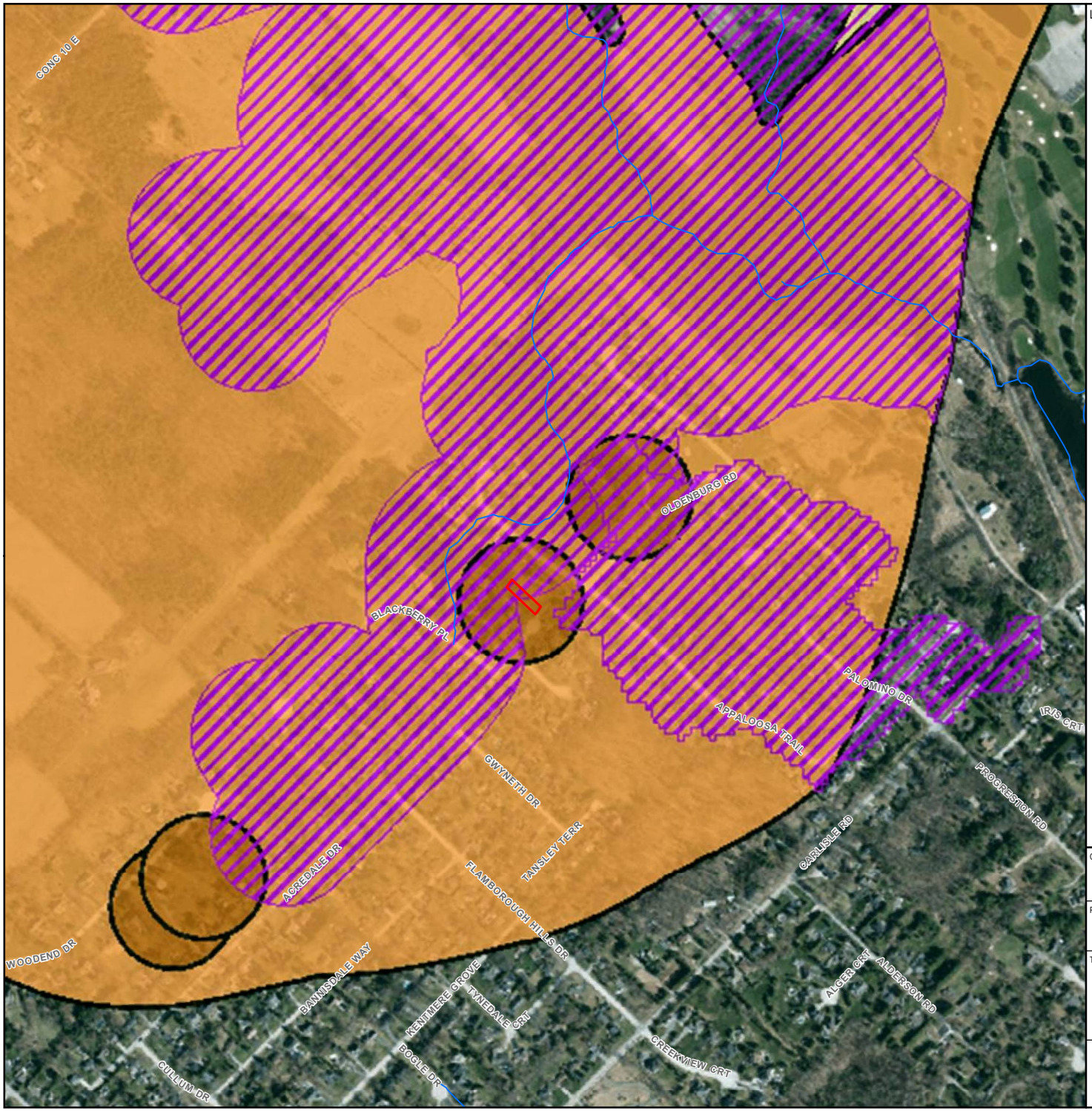
TITLE
Bedrock Geology

Palmer™

REF. NO. 2108704-3-1

Figure 4

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-3-1-Bedrock Geology.mxd



LEGEND

- Subject Site
- Watercourse[1]

Source Water Protection[2]

- Wellhead Protection Area - A
- Wellhead Protection Area - B
- WHPA Groundwater Under Direct Influence (WHPA-E)

1. LIO/MNRF
2. *Source Protection Information Atlas*, MECP © King's Printer for Ontario 2023

0 25 50 100 150 200 250
METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:9,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

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CLIENT
R.V. Anderson Associates

PROJECT
Carlisle Water Storage EA

TITLE
Source Water Protection

Palmer™

REF. NO. 2108704-4a-1

Figure 5a

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-4a-1-Source Water Protection.mxd

LEGEND

Subject Site

Watercourse[1]

Source Water Protection[2]

Highly Vulnerable Aquifer

1. LIO/MNRF
2. *Source Protection Information Atlas*, MECP © King's Printer for Ontario 2023

0 25 50 100 150 200 250
METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:9,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

Source Notes:
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CLIENT
R.V. Anderson Associates

PROJECT
Carlisle Water Storage EA

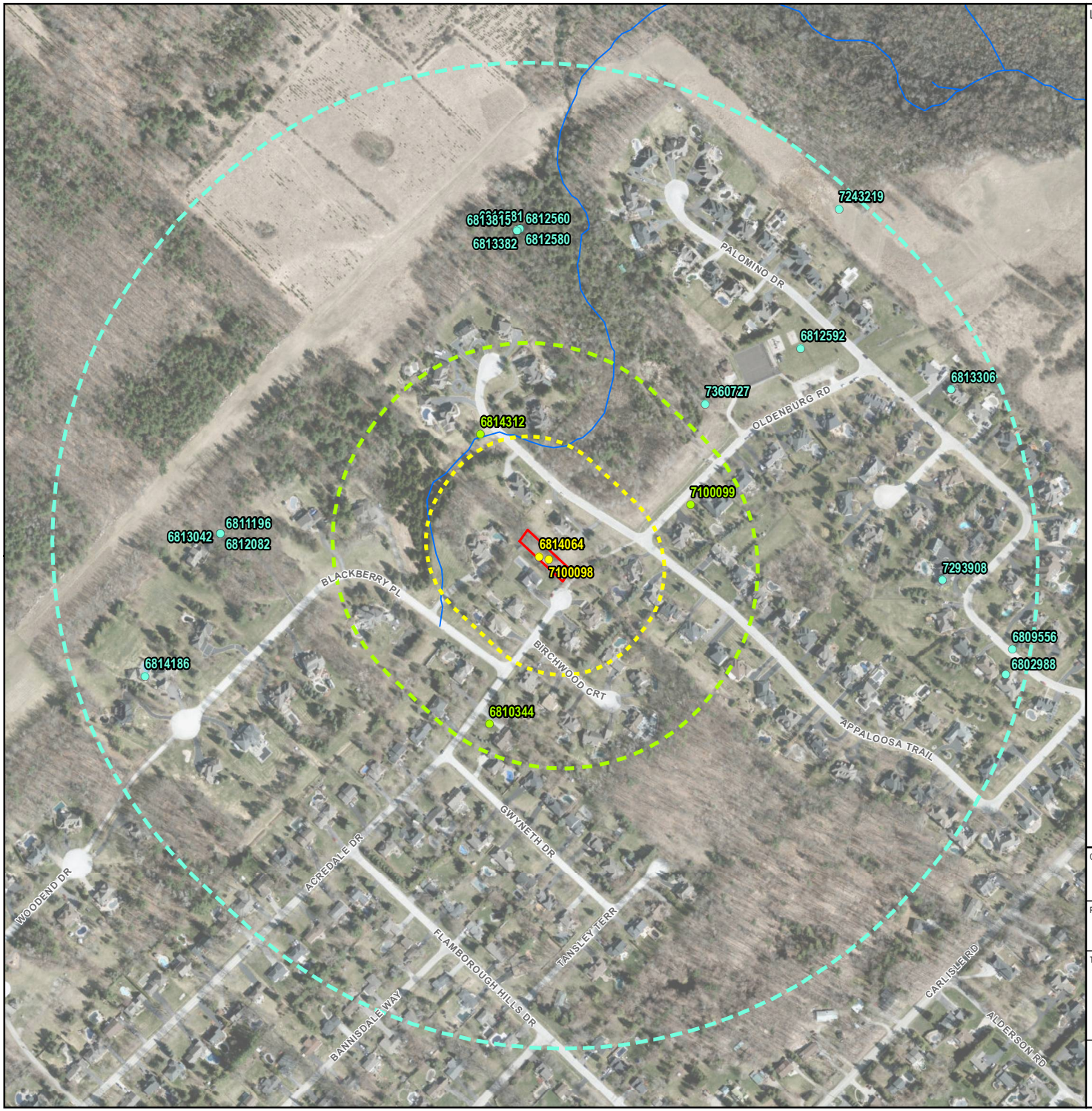
TITLE
Source Water Protection

Palmer™

REF. NO. 2108704-4b-1

Figure 5b

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-4b-1-Source Water Protection.mxd



LEGEND

- Well Record within 500m of site[1]
- Well Record within 200m of site[1]
- Well Record within 100m of site[1]
- Watercourse[2]
- 500m Site Buffer
- 200m Site Buffer
- 100m Site Buffer
- Subject Site

1. MECP
2. LIO/MNRF

0 25 50 100 150 200 250
METRES

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:6,000
Page Size: Letter (8.5 x 11 inches)

Drawn: CV
Checked: LB
Date: Mar 19, 2023

NORTH

Source Notes:
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CLIENT
R.V. Anderson Associates

PROJECT
Carlisle Water Storage EA

TITLE
MECP Well Records within 500m of Site

Palmer

REF. NO. 2108704-5-1

Figure 6

Document Path: G:\Shared drives\Projects 2021 (21001 to 21123)\21087 - R.V. Anderson Associates\2108704 - Carlisle Water Storage EA\GIS\1_Workspace\Task 1 - HydroG Figures\2108704-5-1-MECP Well Records.mxd

Appendix A (MECP Well Records)

WELL_ID	COMPLETED	DEPTH	DP_BE DROCK	STATIC _LEV	WELL_USE	WATER	CASIN G_DIA	PUMP_TEST	FORMATION
6802988	1959-04-17	12.20	0.00	8.80	ST	FR 0029	6	29/32/6/3:0	GRVL BLDR 0040
6809556	1977-01-18	24.40	19.80	6.10	ST DO	FR 0077	6	20/30/20/3:0	PRDR 0007 BRWN FSND LOOS 0060 GREY CSND LOOS 0065 GREY LMSN HARD 0080
6810344	1981-12-02	36.60	34.70	10.10	DO	FR 0059 FR 0105	8 8	33/35/150/24:0	LOAM 0001 BRWN CLAY SAND STNS 0020 BRWN CLAY SAND GRVL 0048 HPAN GRVL 0055 GREY STNS 0073 GREY STNS LTCL 0090 GREY STNS MGRD 0114 BLUE SHLE 0118 RED SHLE 0120
6811196	1987-04-30	14.90	13.70	3.70	DO	FR 0047	6	12/28/36/1:0	BRWN SAND LOOS 0023 BRWN SAND GRVL LOOS 0032 GREY SAND GRVL LOOS 0037 BRWN GRVL SAND LOOS 0045 GREY LMSN HARD 0049
6812082	1991-07-09	18.30	9.80	8.20	CO	UK 0052	6	27/60/1/1:0	BRWN SAND LOOS 0018 BRWN SAND GRVL LOOS 0032 GREY LMSN HARD 0060
6812560	1995-12-21	31.40	12.50	0.00	PS		6 6	//40/:	BRWN SAND GRVL 0036 BRWN SAND 0041 GREY LMSN HARD 0086 GREY LMSN SHLE LYRD 0102 RED SHLE HARD 0103
6812580	1995-02-08	31.70	13.40	8.50	MN	UK 0072 UK 0085	6	28///:	BRWN SAND SILT 0044 GREY ROCK SLTY LYRD 0060 GREY LMSN HARD 0100 BLUE SHLE HARD 0104
6812581	1995-03-07	25.60	6.70	2.40	MN	UK 0041 UK 0044 UK 0049 UK 0053 UK 0060	6	8///:	BRWN SAND SILT STNS 0019 BRWN GRVL 0022 GREY ROCK GRVL LYRD 0027 GREY LMSN HARD 0069 GREY LMSN SHLE LYRD 0081 GREN SHLE 0084
6812592	1995-04-28	25.60	6.70	1.50	AC	UK 0041 UK 0044 UK 0049 UK 0053 UK 0060	8 8	5/16/132/25:0	BRWN SAND SILT STNS 0019 BRWN GRVL 0022 GREY ROCK LYRD 0027 GREY LMSN HARD 0069 GREY LMSN SHLE LYRD 0081 GREN SHLE 0084
6813042	1998-10-21	24.40	15.20	11.90	DO	UK 0075	5	39/40/12/0:30	PRDR 0050 GREY LMSN HARD 0080
6813306	2000-04-26	0.00	0.00	0.00					
6813382	2000-10-06	13.70	9.10	1.50	IR	FR 0033 FR 0036 FR 0039	6 6	5/8/45/:30	BRWN CLAY SNDY LOOS 0006 BRWN SAND LOOS 0020 BRWN SAND GRVL LOOS 0030 GREY LMSN HARD 0045
6813815	2003-03-04	27.40	6.70	4.00	NU	FR 0050 FR 0055 FR 0060 FR 0070	8	13/88/60/1:0	BRWN SAND BLDR GRVL 0022 GREY LMSN DNSE 0088 RED SHLE SOFT 0090
6814064	2004-03-05	32.90	15.20	9.00	MN	FR 0066 FR 0082 FR 0094	8.27	29/40/330/1:30	BRWN CLAY 0003 GREY GRVL 0011 RED SILT SAND STNS 0038 GREY GRVL 0046 BRWN CLAY TILL STNS 0050 GREY LMSN 0078 GREY LMSN 0097 GREY LMSN SHLE 0108
6814186	2004-11-26	22.90	10.70	8.60	DO	0043 0055 0065 0070	5.98	28/30/20/1:0	BRWN CLAY SNDY STNS 0028 BRWN GRVL SAND 0035 GREY LMSN 0075
6814312	2005-07-15	10.70	5.50	4.90	DO	0033 0035	5.98	16/16/20/1:0	BRWN CLAY SNDY STNS 0018 GREY LMSN 0021 BRWN SAND GRVL 0032 GREY LMSN LOOS 0035
7100098	2007-11-28	0.00	0.00	0.00		FR 0033	7.99		
7100099	2007-11-28	0.00	0.00	0.00		FR 0025	7.99		
7243219	2015-05-14	4.60	0.00	0.00	MO		2.04		BRWN SILT FSND GRVL 0015
7293908	2017-08-12	0.00	0.00	1.20	DO	FR 0024		4/30/10/2:0	
7360727	2020-06-15	0.00	0.00	0.00	MN		5.90		

Appendix C

Groundwater Chemistry Analyses

(City of Hamilton Environmental Laboratory)

(York-Durham Regional Environmental Laboratory)

(University of Waterloo, Environmental Isotope Laboratory)

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-01
Date Submitted: 2023-05-01

Laboratory Work Order Number: 343768

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Caffeine SPE GC/MS	Colour Spectrophotometric	Cyanide Skalar
Fluoride-PC Titrate	LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS
Silica Skalar	TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter
Volatile Organics-Purge&Trap/GC/MS			

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
CHEL is accredited by CALA to ISO/IEC 17025 for specific parameters on its scope of accreditation.
" † " indicates the analyte is not accredited to ISO/IEC 17025.

Methods used by the City of Hamilton's Environmental Laboratory (CHEL) are based upon or modified from those found in published reference methods. Specific information on the methods used and equations used for calculated analytes are available upon request.
All analytical work performed at the CHEL is done according to accepted quality assurance and quality control procedures. Quality and other related data as well as uncertainty values are available upon request.

The results on this Certificate of Analysis relate only to the sample as received and analyzed.
Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Hamilton Water					
Well Raw Water Sampling - Carlisle Pump Test					
FDC03RR 2023-05-01 11:00:00 Record 693922					
Alkalinity	346	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	11.8	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	346	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	11.4	me/L	0.1		
Chloride	107	mg/L	0.5		
Colour (apparent)	4	CU	2		
Conductivity	1080	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	0.7	mg/L	0.4		
Fluoride	0.07	mg/L	0.04	1.5	
Ion Balance (Calculation) †	1.5	%	0.1		
Nitrate as N	0.16	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	0.16	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.53	pH	0.01		
pH - Saturation (Calculation) †	6.88	pH	0.01		
Silica-Reactive	10.7	mg/L	0.20		
Sulphate	74.9	mg/L	0.5		
Temperature	21.4	C	0.1		
Total Suspended Solids	<0.6	mg/L	0.6		
Turbidity	0.44	NTU	0.05		
Aluminum	0.008	mg/L	0.002		
Antimony	0.0002	mg/L	0.0001	0.006	
Arsenic	0.0008	mg/L	0.0001	0.010	
Barium	0.0834	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.027	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	114	mg/L	0.05		
Chromium	<0.0001	mg/L	0.0001	0.05	
Cobalt	0.0012	mg/L	0.0001		
Copper	0.0030	mg/L	0.0001		
Hardness (Calculation)	432	mg/L	0.3		
Iron	0.027	mg/L	0.003		
Lead	0.0002	mg/L	0.0001	0.010	
Lithium	0.0056	mg/L	0.0005		
Magnesium	35.9	mg/L	0.05		
Manganese	0.0387	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0006	mg/L	0.0001		
Nickel	0.0051	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	1.61	mg/L	0.05		
Selenium	<0.0001	mg/L	0.0001	0.05	
Silicon	4.94	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	62.9	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Strontium	0.279	mg/L	0.0005	
Thallium	<0.0003	mg/L	0.0003	
Tin	<0.0001	mg/L	0.0001	
Titanium	<0.0004	mg/L	0.0004	
Tungsten	<0.0001	mg/L	0.0001	
Uranium	0.874	ug/L	0.002	20
Vanadium	<0.0001	mg/L	0.0001	
Zinc	0.057	mg/L	0.001	
Zirconium	<0.0004	mg/L	0.0004	
Escherichia coli	0	MPN/100mL	0	0
Total Coliform	0	MPN/100mL	0	0
1,1-Dichloroethylene	<0.2	ug/L	0.2	14
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200
1,2-Dichloroethane	<0.2	ug/L	0.2	5
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5
Benzene	<0.2	ug/L	0.2	1
Bromodichloromethane	<0.2	ug/L	0.2	
Bromoform	<0.2	ug/L	0.2	
Carbon Tetrachloride	<0.2	ug/L	0.2	2
Chlorobenzene	<0.3	ug/L	0.3	80
Chloroform	<0.2	ug/L	0.2	
Dibromochloromethane	<0.2	ug/L	0.2	
Dichloromethane	<0.5	ug/L	0.5	50
Ethylbenzene	<0.2	ug/L	0.2	140
m+p-Xylene	<0.4	ug/L	0.4	
o-Xylene	<0.2	ug/L	0.2	
Tetrachloroethylene	<0.2	ug/L	0.2	10
Toluene	<0.2	ug/L	0.2	60
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90
Caffeine	<0.5	ug/L	0.5	

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-02
Date Submitted: 2023-05-02

Laboratory Work Order Number: 343782

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Colour Spectrophotometric	Cyanide Skalar	Fluoride-PC Titrate
LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS	Silica Skalar
TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
CHEL is accredited by CALA to ISO/IEC 17025 for specific parameters on its scope of accreditation.
" † " indicates the analyte is not accredited to ISO/IEC 17025.

Methods used by the City of Hamilton's Environmental Laboratory (CHEL) are based upon or modified from those found in published reference methods. Specific information on the methods used and equations used for calculated analytes are available upon request.
All analytical work performed at the CHEL is done according to accepted quality assurance and quality control procedures. Quality and other related data as well as uncertainty values are available upon request.

The results on this Certificate of Analysis relate only to the sample as received and analyzed.
Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

ODWS (Amnd O.Reg.457/16) Jan2020 02

Hamilton Water

Well Raw Water Sampling - Carlisle Pump Test

FDC03RR 2023-05-02 10:00:00 Record 693981

Analyte	Result	Units	MDL		
Alkalinity	341	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	11.4	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	341	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	10.8	me/L	0.1		
Chloride	97.9	mg/L	0.5		
Colour (apparent)	<2	CU	2		
Conductivity	1020	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	0.7	mg/L	0.4		
Fluoride	0.07	mg/L	0.04	1.5	
Ion Balance (Calculation) †	3.0	%	0.1		
Nitrate as N	0.29	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	0.29	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.96	pH	0.01		
pH - Saturation (Calculation) †	6.90	pH	0.01		
Silica-Reactive	10.4	mg/L	0.20		
Sulphate	75.1	mg/L	0.5		
Temperature	22.2	C	0.1		
Total Suspended Solids	<0.6	mg/L	0.6		
Turbidity	0.13	NTU	0.05		
Aluminum	<0.002	mg/L	0.002		
Antimony	0.0002	mg/L	0.0001	0.006	
Arsenic	0.0006	mg/L	0.0001	0.010	
Barium	0.0814	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.028	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	108	mg/L	0.05		
Chromium	<0.0001	mg/L	0.0001	0.05	
Cobalt	0.0009	mg/L	0.0001		
Copper	0.0010	mg/L	0.0001		
Hardness (Calculation)	414	mg/L	0.3		
Iron	0.017	mg/L	0.003		
Lead	0.0002	mg/L	0.0001	0.010	
Lithium	0.0054	mg/L	0.0005		
Magnesium	35.1	mg/L	0.05		
Manganese	0.0343	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0006	mg/L	0.0001		
Nickel	0.0039	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	1.57	mg/L	0.05		
Selenium	<0.0001	mg/L	0.0001	0.05	
Silicon	4.62	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	56.0	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Strontium	0.281	mg/L	0.0005	
Thallium	<0.0003	mg/L	0.0003	
Tin	<0.0001	mg/L	0.0001	
Titanium	<0.0004	mg/L	0.0004	
Tungsten	<0.0001	mg/L	0.0001	
Uranium	0.761	ug/L	0.002	20
Vanadium	<0.0001	mg/L	0.0001	
Zinc	0.026	mg/L	0.001	
Zirconium	<0.0004	mg/L	0.0004	
Escherichia coli	0	MPN/100mL	0	0
Total Coliform	0	MPN/100mL	0	0
1,1-Dichloroethylene	<0.2	ug/L	0.2	14
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200
1,2-Dichloroethane	<0.2	ug/L	0.2	5
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5
Benzene	<0.2	ug/L	0.2	1
Bromodichloromethane	<0.2	ug/L	0.2	
Bromoform	<0.2	ug/L	0.2	
Carbon Tetrachloride	<0.2	ug/L	0.2	2
Chlorobenzene	<0.3	ug/L	0.3	80
Chloroform	<0.2	ug/L	0.2	
Dibromochloromethane	<0.2	ug/L	0.2	
Dichloromethane	<0.5	ug/L	0.5	50
Ethylbenzene	<0.2	ug/L	0.2	140
m+p-Xylene	<0.4	ug/L	0.4	
o-Xylene	<0.2	ug/L	0.2	
Tetrachloroethylene	<0.2	ug/L	0.2	10
Toluene	<0.2	ug/L	0.2	60
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-03
Date Submitted: 2023-05-03

Laboratory Work Order Number: 343808

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Colour Spectrophotometric	Cyanide Skalar	Fluoride-PC Titrate
LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS	Silica Skalar
TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
CHEL is accredited by CALA to ISO/IEC 17025 for specific parameters on its scope of accreditation.
" † " indicates the analyte is not accredited to ISO/IEC 17025.

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Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Hamilton Water					
Well Raw Water Sampling - Carlisle Pump Test					
FDC03RR 2023-05-03 10:00:00 Record 694096					
Alkalinity	322	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	11.1	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	322	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	11.4	me/L	0.1		
Chloride	97.8	mg/L	0.5		
Colour (apparent)	<2	CU	2		
Conductivity	1020	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	0.6	mg/L	0.4		
Fluoride	0.07	mg/L	0.04	1.5	
Ion Balance (Calculation) †	1.3	%	0.1		
Nitrate as N	0.38	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	0.38	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.70	pH	0.01		
pH - Saturation (Calculation) †	6.88	pH	0.01		
Silica-Reactive	10.4	mg/L	0.20		
Sulphate	75.4	mg/L	0.5		
Temperature	22.3	C	0.1		
Total Suspended Solids	<0.7	mg/L	0.7		
Turbidity	0.14	NTU	0.05		
Aluminum	<0.002	mg/L	0.002		
Antimony	0.0002	mg/L	0.0001	0.006	
Arsenic	0.0006	mg/L	0.0001	0.010	
Barium	0.0805	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.025	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	118	mg/L	0.05		
Chromium	<0.0001	mg/L	0.0001	0.05	
Cobalt	0.0008	mg/L	0.0001		
Copper	0.0011	mg/L	0.0001		
Hardness (Calculation)	442	mg/L	0.3		
Iron	0.014	mg/L	0.003		
Lead	0.0002	mg/L	0.0001	0.010	
Lithium	0.0049	mg/L	0.0005		
Magnesium	35.9	mg/L	0.05		
Manganese	0.0312	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0005	mg/L	0.0001		
Nickel	0.0036	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	1.64	mg/L	0.05		
Selenium	<0.0001	mg/L	0.0001	0.05	
Silicon	4.49	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	56.5	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Strontium	0.281	mg/L	0.0005	
Thallium	<0.0003	mg/L	0.0003	
Tin	<0.0001	mg/L	0.0001	
Titanium	<0.0004	mg/L	0.0004	
Tungsten	<0.0001	mg/L	0.0001	
Uranium	0.781	ug/L	0.002	20
Vanadium	<0.0001	mg/L	0.0001	
Zinc	0.027	mg/L	0.001	
Zirconium	<0.0004	mg/L	0.0004	
Escherichia coli	0	MPN/100mL	0	0
Total Coliform	0	MPN/100mL	0	0
1,1-Dichloroethylene	<0.2	ug/L	0.2	14
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200
1,2-Dichloroethane	<0.2	ug/L	0.2	5
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5
Benzene	<0.2	ug/L	0.2	1
Bromodichloromethane	<0.2	ug/L	0.2	
Bromoform	<0.2	ug/L	0.2	
Carbon Tetrachloride	<0.2	ug/L	0.2	2
Chlorobenzene	<0.3	ug/L	0.3	80
Chloroform	<0.2	ug/L	0.2	
Dibromochloromethane	<0.2	ug/L	0.2	
Dichloromethane	<0.5	ug/L	0.5	50
Ethylbenzene	<0.2	ug/L	0.2	140
m+p-Xylene	<0.4	ug/L	0.4	
o-Xylene	<0.2	ug/L	0.2	
Tetrachloroethylene	<0.2	ug/L	0.2	10
Toluene	<0.2	ug/L	0.2	60
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-04
Date Submitted: 2023-05-04

Laboratory Work Order Number: 343830

Samples in this work order were analyzed using the following methods:

Microcystin ADDA

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
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Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

	Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Hamilton Water					
Well Raw Water Sampling - Carlisle Pump Test					
FDC03RR 2023-05-04 10:30:00 Record 694165					
	Microcystins	<0.15	ug/L	0.15	1.5

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-04
Date Submitted: 2023-05-04

Laboratory Work Order Number: 343829

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Caffeine SPE GC/MS	Colour Spectrophotometric	Cyanide Skalar
Fluoride-PC Titrate	LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS
Silica Skalar	Subcontract	TOC/DOC Colourimetric	TSS/VSS Gravimetric
Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS		

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Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
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Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Jillian J. Thompson-Anderson
Quality Control Automation Technologist

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02

Hamilton Water

Well Raw Water Sampling - Carlisle Pump Test

FDC03RR 2023-05-04 10:30:00 Record 694163

Alkalinity	339	mg/L	2	
Ammonia + Ammonium as N	<0.01	mg/L	0.01	
Anion Sum (Calculation) †	11.3	me/L	0.1	
Bicarbonate as Carbonate (Calculation)	339	mg/L	2	
Bromide	<0.2	mg/L	0.2	
Cation Sum (Calculation) †	11.2	me/L	0.1	
Chloride	95.9	mg/L	0.5	
Colour (apparent)	<2	CU	2	
Conductivity	1030	umhos/cm	4	
Cyanide - Total	<0.003	mg/L	0.003	0.2
Dissolved Organic Carbon	0.8	mg/L	0.4	
Fluoride	0.07	mg/L	0.04	1.5
Ion Balance (Calculation) †	0.4	%	0.1	
Nitrate as N	0.44	mg/L	0.02	10.0
Nitrate+Nitrite as N (Calculation)	0.45	mg/L	0.03	
Nitrite as N	0.01	mg/L	0.01	1.0
o-Phosphate as P	<0.05	mg/L	0.05	
pH	7.78	pH	0.01	
pH - Saturation (Calculation) †	6.87	pH	0.01	
Silica-Reactive	10.3	mg/L	0.20	
Sulphate	74.0	mg/L	0.5	
Temperature	22.6	C	0.1	
Total Organic Carbon	0.7	mg/L	0.4	
Total Suspended Solids	IS	mg/L	0.6	
Turbidity	0.10	NTU	0.05	
Aluminum	<0.002	mg/L	0.002	
Antimony	0.0003	mg/L	0.0001	0.006
Arsenic	0.0005	mg/L	0.0001	0.010
Barium	0.0791	mg/L	0.0001	1.0
Beryllium	<0.0001	mg/L	0.0001	
Bismuth	<0.0001	mg/L	0.0001	
Boron	0.028	mg/L	0.010	5.0
Cadmium	<0.0001	mg/L	0.0001	0.005
Calcium	116	mg/L	0.05	
Chromium	<0.0001	mg/L	0.0001	0.05
Cobalt	0.0008	mg/L	0.0001	
Copper	0.0011	mg/L	0.0001	
Hardness (Calculation)	437	mg/L	0.3	
Iron	0.011	mg/L	0.003	
Lead	0.0002	mg/L	0.0001	0.010
Lithium	0.0051	mg/L	0.0005	
Magnesium	35.9	mg/L	0.05	
Manganese	0.0302	mg/L	0.0001	
Mercury	<0.05	ug/L	0.05	1
Molybdenum	0.0006	mg/L	0.0001	
Nickel	0.0036	mg/L	0.0001	
Phosphorus Total	<0.010	mg/L	0.010	
Potassium	1.63	mg/L	0.05	
Selenium	<0.0001	mg/L	0.0001	0.05
Silicon	4.27	mg/L	0.01	
Silver	<0.0001	mg/L	0.0001	

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Sodium	56.1	mg/L	0.05	20	*
Strontium	0.281	mg/L	0.0005		
Thallium	<0.0003	mg/L	0.0003		
Tin	<0.0001	mg/L	0.0001		
Titanium	<0.0004	mg/L	0.0004		
Tungsten	<0.0001	mg/L	0.0001		
Uranium	0.774	ug/L	0.002	20	
Vanadium	<0.0001	mg/L	0.0001		
Zinc	0.030	mg/L	0.001		
Zirconium	<0.0004	mg/L	0.0004		
Escherichia coli	0	MPN/100mL	0	0	
Total Coliform	0	MPN/100mL	0	0	
1,1-Dichloroethylene	<0.2	ug/L	0.2	14	
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200	
1,2-Dichloroethane	<0.2	ug/L	0.2	5	
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5	
Benzene	<0.2	ug/L	0.2	1	
Bromodichloromethane	<0.2	ug/L	0.2		
Bromoform	<0.2	ug/L	0.2		
Carbon Tetrachloride	<0.2	ug/L	0.2	2	
Chlorobenzene	<0.3	ug/L	0.3	80	
Chloroform	<0.2	ug/L	0.2		
Dibromochloromethane	<0.2	ug/L	0.2		
Dichloromethane	<0.5	ug/L	0.5	50	
Ethylbenzene	<0.2	ug/L	0.2	140	
m+p-Xylene	<0.4	ug/L	0.4		
o-Xylene	<0.2	ug/L	0.2		
Tetrachloroethylene	<0.2	ug/L	0.2	10	
Toluene	<0.2	ug/L	0.2	60	
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100	
Trichloroethylene	<0.2	ug/L	0.2	5	
Vinyl Chloride	<0.2	ug/L	0.2	1	
Xylene (Calculation)	<0.5	ug/L	0.5	90	
2,3,4,6-Tetrachlorophenol (Subcontract)	<0.20	ug/L	0.2	100	
2,4,6-Trichlorophenol (Subcontract)	<0.25	ug/L	0.25	5	
2,4-D (Subcontract)	<0.19	ug/L	0.19	100	
2,4-Dichlorophenol (Subcontract)	<0.15	ug/L	0.15	900	
Alachlor (Subcontract)	<0.02	ug/L	0.02	5	
Atrazine (Subcontract)	<0.01	ug/L	0.01		
Atrazine + Desethyl-atrazine (Subcontract)	<0.01	ug/L	0.01	5	
Azinphos-methyl (Subcontract)	<0.05	ug/L	0.05	20	
Benzo[a]pyrene (Subcontract)	<0.004	ug/L	0.004	0.01	
Bromate (Subcontract)	<0.005	mg/L	0.005	10	
Bromoxynil (Subcontract)	<0.33	ug/L	0.33	5	
Carbaryl (Subcontract)	<0.05	ug/L	0.05	90	
Carbofuran (Subcontract)	<0.01	ug/L	0.01	90	
Chlorate (Subcontract)	0.02	mg/L	0.01	1.0	
Chlorite (Subcontract)	<0.01	mg/L	0.01	1.0	
Chlorpyrifos (Dursban) (Subcontract)	<0.02	ug/L	0.02	90	
Desethyl-atrazine (Subcontract)	<0.01	ug/L	0.01		
Diazinon (Subcontract)	<0.02	ug/L	0.02	20	
Dicamba (Subcontract)	<0.20	ug/L	0.20	120	
Diclofop-methyl (Subcontract)	<0.40	ug/L	0.40	9	
Dimethoate (Subcontract)	<0.06	ug/L	0.06	20	
Diquat (Subcontract)	<1	ug/L	1	70	
Diuron (Subcontract)	<0.03	ug/L	0.03	150	
Glyphosate (Subcontract)	<1	ug/L	1	280	

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Gross Alpha (Subcontract)	<0.10	Bq/L	0.10	
Gross Beta (Subcontract)	<0.10	Bq/L	0.10	
Haloacetic Acids (Subcontract)	<5.3	ug/L	5	80
Malathion (Subcontract)	<0.02	ug/L	0.02	190
MCPA (Subcontract)	<0.00012	mg/L	0.00012	0.1
Metolachlor (Subcontract)	<0.01	ug/L	0.01	50
Metribuzin (Sencor) (Subcontract)	<0.02	ug/L	0.02	80
NDMA (Subcontract)	<0.0009	ug/L	0.0008	0.009
Nitrilotriacetic Acid (Subcontract)	<0.03	mg/L	0.03	400
Paraquat (Subcontract)	<1	ug/L	1	10
PCBsTotal (Subcontract)	<0.04	ug/L	0.04	3.0
Pentachlorophenol (Subcontract)	<0.15	ug/L	0.15	60
Phorate (Subcontract)	<0.01	ug/L	0.01	2
Picloram (Subcontract)	<1	ug/L	1	190
Prometryne (Subcontract)	<0.03	ug/L	0.03	1
Simazine (Subcontract)	<0.01	ug/L	0.01	10
Terbufos (Subcontract)	<0.01	ug/L	0.01	1
Total Toxic Equivalency (Subcontract)	4.51			
Triallate (Subcontract)	<0.01	ug/L	0.01	230
Trifluralin (Subcontract)	<0.02	ug/L	0.02	45
Tritium (Subcontract)	<15	Bq/L	15	
Caffeine	<0.5	ug/L	0.5	

Note: Picloram QC recovery was low; actual result may be higher.

FDC03R 2023-05-04 10:15:00 Record 694164

Alkalinity	324	mg/L	2	
Ammonia + Ammonium as N	<0.01	mg/L	0.01	
Anion Sum (Calculation) †	10.2	me/L	0.1	
Bicarbonate as Carbonate (Calculation)	324	mg/L	2	
Bromide	<0.2	mg/L	0.2	
Cation Sum (Calculation) †	10.4	me/L	0.1	
Chloride	74.1	mg/L	0.5	
Colour (apparent)	30	CU	2	
Conductivity	913	umhos/cm	4	
Cyanide - Total	<0.003	mg/L	0.003	0.2
Dissolved Organic Carbon	1.0	mg/L	0.4	
Fluoride	0.07	mg/L	0.04	1.5
Ion Balance (Calculation) †	1.4	%	0.1	
Nitrate as N	1.81	mg/L	0.02	10.0
Nitrate+Nitrite as N (Calculation)	1.81	mg/L	0.03	
Nitrite as N	<0.01	mg/L	0.01	1.0
o-Phosphate as P	<0.05	mg/L	0.05	
pH	7.89	pH	0.01	
pH - Saturation (Calculation) †	6.89	pH	0.01	
Silica-Reactive	10.1	mg/L	0.20	
Sulphate	57.0	mg/L	0.5	
Temperature	22.8	C	0.1	
Total Suspended Solids	3.7	mg/L	0.6	
Turbidity	6.52	NTU	0.05	
Aluminum	0.239	mg/L	0.002	
Antimony	0.0004	mg/L	0.0001	0.006
Arsenic	0.0007	mg/L	0.0001	0.010
Barium	0.105	mg/L	0.0001	1.0
Beryllium	<0.0001	mg/L	0.0001	
Bismuth	<0.0001	mg/L	0.0001	
Boron	0.023	mg/L	0.010	5.0
Cadmium	<0.0001	mg/L	0.0001	0.005

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Calcium	111	mg/L	0.05		
Chromium	0.0072	mg/L	0.0001	0.05	
Cobalt	0.0016	mg/L	0.0001		
Copper	0.0015	mg/L	0.0001		
Hardness (Calculation)	420	mg/L	0.3		
Iron	0.933	mg/L	0.003		
Lead	0.0004	mg/L	0.0001	0.010	
Lithium	0.0054	mg/L	0.0005		
Magnesium	34.7	mg/L	0.05		
Manganese	0.0460	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0009	mg/L	0.0001		
Nickel	0.0103	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	3.48	mg/L	0.05		
Selenium	0.0002	mg/L	0.0001	0.05	
Silicon	5.34	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	43.3	mg/L	0.05	20	*
Strontium	0.201	mg/L	0.0005		
Thallium	<0.0003	mg/L	0.0003		
Tin	0.0014	mg/L	0.0001		
Titanium	0.0135	mg/L	0.0004		
Tungsten	<0.0001	mg/L	0.0001		
Uranium	0.716	ug/L	0.002	20	
Vanadium	0.0003	mg/L	0.0001		
Zinc	0.009	mg/L	0.001		
Zirconium	0.0004	mg/L	0.0004		
Escherichia coli	0	MPN/100mL	0	0	
Total Coliform	0	MPN/100mL	0	0	
1,1-Dichloroethylene	<0.2	ug/L	0.2	14	
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200	
1,2-Dichloroethane	<0.2	ug/L	0.2	5	
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5	
Benzene	<0.2	ug/L	0.2	1	
Bromodichloromethane	<0.2	ug/L	0.2		
Bromoform	<0.2	ug/L	0.2		
Carbon Tetrachloride	<0.2	ug/L	0.2	2	
Chlorobenzene	<0.3	ug/L	0.3	80	
Chloroform	<0.2	ug/L	0.2		
Dibromochloromethane	<0.2	ug/L	0.2		
Dichloromethane	<0.5	ug/L	0.5	50	
Ethylbenzene	<0.2	ug/L	0.2	140	
m+p-Xylene	<0.4	ug/L	0.4		
o-Xylene	<0.2	ug/L	0.2		
Tetrachloroethylene	<0.2	ug/L	0.2	10	
Toluene	<0.2	ug/L	0.2	60	
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100	
Trichloroethylene	<0.2	ug/L	0.2	5	
Vinyl Chloride	<0.2	ug/L	0.2	1	
Xylene (Calculation)	<0.5	ug/L	0.5	90	

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-04-17
Date Submitted: 2023-04-17

Laboratory Work Order Number: 343604

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Colour Spectrophotometric	Cyanide Skalar	Fluoride-PC Titrate
LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS	Silica Skalar
TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
CHEL is accredited by CALA to ISO/IEC 17025 for specific parameters on its scope of accreditation.
" † " indicates the analyte is not accredited to ISO/IEC 17025.

Methods used by the City of Hamilton's Environmental Laboratory (CHEL) are based upon or modified from those found in published reference methods. Specific information on the methods used and equations used for calculated analytes are available upon request.
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The results on this Certificate of Analysis relate only to the sample as received and analyzed.
Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Hamilton Water					
Well Raw Water Sampling - Carlisle Pump Test					
FDC03R 2023-04-17 09:45:00 Record 692471					
Alkalinity	331	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	10.2	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	331	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	10.6	me/L	0.1		
Chloride	68.5	mg/L	0.5		
Colour (apparent)	16	CU	2		
Conductivity	888	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	0.7	mg/L	0.4		
Fluoride	0.07	mg/L	0.04	1.5	
Ion Balance (Calculation) †	2.0	%	0.1		
Nitrate as N	0.91	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	0.91	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.77	pH	0.01		
pH - Saturation (Calculation) †	6.89	pH	0.01		
Silica-Reactive	9.77	mg/L	0.20		
Sulphate	61.5	mg/L	0.5		
Temperature	21.3	C	0.1		
Total Suspended Solids	49.6	mg/L	0.6		
Turbidity	2.24	NTU	0.05		
Aluminum	0.344	mg/L	0.002		
Antimony	0.0004	mg/L	0.0001	0.006	
Arsenic	0.0011	mg/L	0.0001	0.010	
Barium	0.103	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.022	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	116	mg/L	0.05		
Chromium	0.0074	mg/L	0.0001	0.05	
Cobalt	0.0024	mg/L	0.0001		
Copper	0.0029	mg/L	0.0001		
Hardness (Calculation)	436	mg/L	0.3		
Iron	1.87	mg/L	0.003		
Lead	0.0007	mg/L	0.0001	0.010	
Lithium	0.0047	mg/L	0.0005		
Magnesium	35.6	mg/L	0.05		
Manganese	0.0999	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0010	mg/L	0.0001		
Nickel	0.0076	mg/L	0.0001		
Phosphorus Total	0.012	mg/L	0.010		
Potassium	1.81	mg/L	0.05		
Selenium	0.0001	mg/L	0.0001	0.05	
Silicon	5.35	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	39.0	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Strontium	0.228	mg/L	0.0005	
Thallium	<0.0003	mg/L	0.0003	
Tin	0.0054	mg/L	0.0001	
Titanium	0.0185	mg/L	0.0004	
Tungsten	<0.0001	mg/L	0.0001	
Uranium	0.683	ug/L	0.002	20
Vanadium	0.0004	mg/L	0.0001	
Zinc	0.027	mg/L	0.001	
Zirconium	0.0004	mg/L	0.0004	
Escherichia coli	0	MPN/100mL	0	0
Total Coliform	0	MPN/100mL	0	0
1,1-Dichloroethylene	<0.2	ug/L	0.2	14
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200
1,2-Dichloroethane	<0.2	ug/L	0.2	5
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5
Benzene	<0.2	ug/L	0.2	1
Bromodichloromethane	<0.2	ug/L	0.2	
Bromoform	<0.2	ug/L	0.2	
Carbon Tetrachloride	<0.2	ug/L	0.2	2
Chlorobenzene	<0.3	ug/L	0.3	80
Chloroform	<0.2	ug/L	0.2	
Dibromochloromethane	<0.2	ug/L	0.2	
Dichloromethane	<0.5	ug/L	0.5	50
Ethylbenzene	<0.2	ug/L	0.2	140
m+p-Xylene	<0.4	ug/L	0.4	
o-Xylene	<0.2	ug/L	0.2	
Tetrachloroethylene	<0.2	ug/L	0.2	10
Toluene	<0.2	ug/L	0.2	60
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-04-11
Date Submitted: 2023-04-11

Laboratory Work Order Number: 343559

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Colour Spectrophotometric	Cyanide Skalar	Fluoride-PC Titrate
LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS	Silica Skalar
TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
CHEL is accredited by CALA to ISO/IEC 17025 for specific parameters on its scope of accreditation.
" † " indicates the analyte is not accredited to ISO/IEC 17025.

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The results on this Certificate of Analysis relate only to the sample as received and analyzed.
Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Jillian J. Thompson-Anderson
Quality Control Automation Technologist

ODWS (Amnd O.Reg.457/16) Jan2020 02

Hamilton Water

Monitoring Well - Carlisle GW - Pre Pump Test

CM-03-03-S 2023-04-11 13:00:00 Record 692250

Analyte	Result	Units	MDL		
Alkalinity	393	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	17.9	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	393	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	16.5	me/L	0.1		
Chloride	263	mg/L	0.5		
Colour (apparent)	2	CU	2		
Conductivity	1680	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	1.2	mg/L	0.4		
Fluoride	0.04	mg/L	0.04	1.5	
Ion Balance (Calculation) †	4.1	%	0.1		
Nitrate as N	3.62	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	3.62	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.68	pH	0.01		
pH - Saturation (Calculation) †	6.76	pH	0.01		
Silica-Reactive	16.6	mg/L	0.20		
Sulphate	90.5	mg/L	0.5		
Temperature	20.8	C	0.1		
Total Suspended Solids	<1	mg/L	1		
Turbidity	0.39	NTU	0.05		
Aluminum	0.006	mg/L	0.002		
Antimony	<0.0001	mg/L	0.0001	0.006	
Arsenic	0.0002	mg/L	0.0001	0.010	
Barium	0.0622	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.015	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	150	mg/L	0.05		
Chromium	0.0014	mg/L	0.0001	0.05	
Cobalt	<0.0001	mg/L	0.0001		
Copper	0.0005	mg/L	0.0001		
Hardness (Calculation)	489	mg/L	0.3		
Iron	0.015	mg/L	0.003		
Lead	<0.0001	mg/L	0.0001	0.010	
Lithium	0.0030	mg/L	0.0005		
Magnesium	27.8	mg/L	0.05		
Manganese	0.0006	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	<0.0001	mg/L	0.0001		
Nickel	0.0002	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	0.39	mg/L	0.05		
Selenium	0.0007	mg/L	0.0001	0.05	
Silicon	8.20	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	153	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Strontium	0.282	mg/L	0.0005	
Thallium	<0.0003	mg/L	0.0003	
Tin	<0.0001	mg/L	0.0001	
Titanium	0.0007	mg/L	0.0004	
Tungsten	0.0001	mg/L	0.0001	
Uranium	0.220	ug/L	0.002	20
Vanadium	0.0002	mg/L	0.0001	
Zinc	<0.001	mg/L	0.001	
Zirconium	<0.0004	mg/L	0.0004	
Escherichia coli	0	MPN/100mL	0	0
Total Coliform	0	MPN/100mL	0	0
1,1-Dichloroethylene	<0.2	ug/L	0.2	14
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200
1,2-Dichloroethane	<0.2	ug/L	0.2	5
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5
Benzene	<0.2	ug/L	0.2	1
Bromodichloromethane	<0.2	ug/L	0.2	
Bromoform	<0.2	ug/L	0.2	
Carbon Tetrachloride	<0.2	ug/L	0.2	2
Chlorobenzene	<0.3	ug/L	0.3	80
Chloroform	<0.2	ug/L	0.2	
Dibromochloromethane	<0.2	ug/L	0.2	
Dichloromethane	<0.5	ug/L	0.5	50
Ethylbenzene	<0.2	ug/L	0.2	140
m+p-Xylene	<0.4	ug/L	0.4	
o-Xylene	<0.2	ug/L	0.2	
Tetrachloroethylene	<0.2	ug/L	0.2	10
Toluene	<0.2	ug/L	0.2	60
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

CM-03-03-D 2023-04-11 14:30:00 Record 692251

Alkalinity	302	mg/L	2	
Ammonia + Ammonium as N	<0.01	mg/L	0.01	
Anion Sum (Calculation) †	9.8	me/L	0.1	
Bicarbonate as Carbonate (Calculation)	302	mg/L	2	
Bromide	<0.2	mg/L	0.2	
Cation Sum (Calculation) †	9.5	me/L	0.1	
Chloride	83.1	mg/L	0.5	
Colour (apparent)	29	CU	2	
Conductivity	897	umhos/cm	4	
Cyanide - Total	<0.003	mg/L	0.003	0.2
Dissolved Organic Carbon	1.2	mg/L	0.4	
Fluoride	0.06	mg/L	0.04	1.5
Ion Balance (Calculation) †	1.8	%	0.1	
Nitrate as N	2.26	mg/L	0.02	10.0
Nitrate+Nitrite as N (Calculation)	2.26	mg/L	0.03	
Nitrite as N	<0.01	mg/L	0.01	1.0
o-Phosphate as P	<0.05	mg/L	0.05	
pH	7.71	pH	0.01	
pH - Saturation (Calculation) †	6.97	pH	0.01	
Silica-Reactive	9.82	mg/L	0.20	
Sulphate	49.0	mg/L	0.5	
Temperature	21.2	C	0.1	

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Total Suspended Solids	2.7	mg/L	0.6		
Turbidity	9.77	NTU	0.05		
Aluminum	0.002	mg/L	0.002		
Antimony	<0.0001	mg/L	0.0001	0.006	
Arsenic	0.0002	mg/L	0.0001	0.010	
Barium	0.0985	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.019	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	102	mg/L	0.05		
Chromium	0.0002	mg/L	0.0001	0.05	
Cobalt	<0.0001	mg/L	0.0001		
Copper	0.0022	mg/L	0.0001		
Hardness (Calculation)	376	mg/L	0.3		
Iron	1.40	mg/L	0.003		
Lead	<0.0001	mg/L	0.0001	0.010	
Lithium	0.0030	mg/L	0.0005		
Magnesium	29.4	mg/L	0.05		
Manganese	0.0048	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0008	mg/L	0.0001		
Nickel	0.0010	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	1.38	mg/L	0.05		
Selenium	0.0002	mg/L	0.0001	0.05	
Silicon	4.95	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	42.8	mg/L	0.05	20	*
Strontium	0.311	mg/L	0.0005		
Thallium	<0.0003	mg/L	0.0003		
Tin	<0.0001	mg/L	0.0001		
Titanium	0.0004	mg/L	0.0004		
Tungsten	<0.0001	mg/L	0.0001		
Uranium	0.392	ug/L	0.002	20	
Vanadium	<0.0001	mg/L	0.0001		
Zinc	0.012	mg/L	0.001		
Zirconium	<0.0004	mg/L	0.0004		
Escherichia coli	0	MPN/100mL	0	0	
Total Coliform	1	MPN/100mL	0	0	*
1,1-Dichloroethylene	<0.2	ug/L	0.2	14	
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200	
1,2-Dichloroethane	<0.2	ug/L	0.2	5	
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5	
Benzene	<0.2	ug/L	0.2	1	
Bromodichloromethane	<0.2	ug/L	0.2		
Bromoform	<0.2	ug/L	0.2		
Carbon Tetrachloride	<0.2	ug/L	0.2	2	
Chlorobenzene	<0.3	ug/L	0.3	80	
Chloroform	<0.2	ug/L	0.2		
Dibromochloromethane	<0.2	ug/L	0.2		
Dichloromethane	<0.5	ug/L	0.5	50	
Ethylbenzene	<0.2	ug/L	0.2	140	
m+p-Xylene	<0.4	ug/L	0.4		
o-Xylene	<0.2	ug/L	0.2		
Tetrachloroethylene	<0.2	ug/L	0.2	10	
Toluene	<0.2	ug/L	0.2	60	

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Certificate of Analysis

City of Hamilton
Environmental Laboratory
700 Woodward Avenue, Hamilton, ON L8H 6P4
P. (905) 546-2424 F. (905)545-0234

CLIENT INFORMATION

Client Name: HAMILTON WATER
Attention: CARMEN VEGA

Address: 100 KING STREET WEST, LEVEL 9
HAMILTON
L8P 1A2

LABORATORY INFORMATION

Sample Date: 2023-05-10
Date Submitted: 2023-05-10

Laboratory Work Order Number: 343911

Samples in this work order were analyzed using the following methods:

o-Phosphate Colourimetric	Alk/pH/Cond/Temp PC Titrate	Ammonia Skalar	Anions IC
Bacteria MPN	Colour Spectrophotometric	Cyanide Skalar	Fluoride-PC Titrate
LIMS Calculation	Mercury Cold Vapour AA	Metals ICP/MS	Silica Skalar
TOC/DOC Colourimetric	TSS/VSS Gravimetric	Turbidity Turbimeter	Volatile Organics-Purge&Trap/GC/MS

NOTES:
'<' = less than the Method Detection Limit (MDL), 'IS' = Insufficient Sample, '>' = greater than the reported result.
Results have been compared to the stated specification, without taking into account measurement uncertainty. An asterisk (*) indicates the result has been found to be outside of that specification.
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" † " indicates the analyte is not accredited to ISO/IEC 17025.

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Field data provided by the customer is identified as such and can affect the validity of CHEL's results.

Final Report Approval by:

Mira Bogle
Environmental Compliance Technologist

Hamilton Water

Monitoring Well - Carlisle GW - Post Pump Test

CM-03-03-S 2023-05-10 14:50:00 Record 694645

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Alkalinity	363	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	12.8	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	363	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	12.5	me/L	0.1		
Chloride	130	mg/L	0.5		
Colour (apparent)	6	CU	2		
Conductivity	1170	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	1.4	mg/L	0.4		
Fluoride	0.05	mg/L	0.04	1.5	
Ion Balance (Calculation) †	0.9	%	0.1		
Nitrate as N	3.06	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	3.06	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.60	pH	0.01		
pH - Saturation (Calculation) †	6.86	pH	0.01		
Silica-Reactive	16.3	mg/L	0.20		
Sulphate	57.3	mg/L	0.5		
Temperature	20.9	C	0.1		
Total Suspended Solids	1.6	mg/L	0.6		
Turbidity	0.72	NTU	0.05		
Aluminum	0.020	mg/L	0.002		
Antimony	<0.0001	mg/L	0.0001	0.006	
Arsenic	0.0002	mg/L	0.0001	0.010	
Barium	0.0379	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.014	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	117	mg/L	0.05		
Chromium	0.0012	mg/L	0.0001	0.05	
Cobalt	<0.0001	mg/L	0.0001		
Copper	0.0005	mg/L	0.0001		
Hardness (Calculation)	393	mg/L	0.3		
Iron	0.027	mg/L	0.003		
Lead	<0.0001	mg/L	0.0001	0.010	
Lithium	0.0025	mg/L	0.0005		
Magnesium	24.6	mg/L	0.05		
Manganese	0.0017	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	<0.0001	mg/L	0.0001		
Nickel	0.0002	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	0.34	mg/L	0.05		
Selenium	0.0010	mg/L	0.0001	0.05	
Silicon	6.97	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	107	mg/L	0.05	20	*

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Strontium	0.205	mg/L	0.0005		
Thallium	<0.0003	mg/L	0.0003		
Tin	<0.0001	mg/L	0.0001		
Titanium	0.0012	mg/L	0.0004		
Tungsten	0.0001	mg/L	0.0001		
Uranium	0.168	ug/L	0.002	20	
Vanadium	0.0003	mg/L	0.0001		
Zinc	<0.001	mg/L	0.001		
Zirconium	<0.0004	mg/L	0.0004		
Escherichia coli	0	MPN/100mL	0	0	
Total Coliform	2	MPN/100mL	0	0	*
1,1-Dichloroethylene	<0.2	ug/L	0.2	14	
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200	
1,2-Dichloroethane	<0.2	ug/L	0.2	5	
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5	
Benzene	<0.2	ug/L	0.2	1	
Bromodichloromethane	<0.2	ug/L	0.2		
Bromoform	<0.2	ug/L	0.2		
Carbon Tetrachloride	<0.2	ug/L	0.2	2	
Chlorobenzene	<0.3	ug/L	0.3	80	
Chloroform	<0.2	ug/L	0.2		
Dibromochloromethane	<0.2	ug/L	0.2		
Dichloromethane	<0.5	ug/L	0.5	50	
Ethylbenzene	<0.2	ug/L	0.2	140	
m+p-Xylene	<0.4	ug/L	0.4		
o-Xylene	<0.2	ug/L	0.2		
Tetrachloroethylene	<0.2	ug/L	0.2	10	
Toluene	<0.2	ug/L	0.2	60	
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100	
Trichloroethylene	<0.2	ug/L	0.2	5	
Vinyl Chloride	<0.2	ug/L	0.2	1	
Xylene (Calculation)	<0.5	ug/L	0.5	90	

CM-03-03-D 2023-05-10 13:00:00 Record 694646

Alkalinity	308	mg/L	2		
Ammonia + Ammonium as N	<0.01	mg/L	0.01		
Anion Sum (Calculation) †	9.9	me/L	0.1		
Bicarbonate as Carbonate (Calculation)	308	mg/L	2		
Bromide	<0.2	mg/L	0.2		
Cation Sum (Calculation) †	10.0	me/L	0.1		
Chloride	81.0	mg/L	0.5		
Colour (apparent)	19	CU	2		
Conductivity	906	umhos/cm	4		
Cyanide - Total	<0.003	mg/L	0.003	0.2	
Dissolved Organic Carbon	1.1	mg/L	0.4		
Fluoride	0.07	mg/L	0.04	1.5	
Ion Balance (Calculation) †	0.3	%	0.1		
Nitrate as N	2.63	mg/L	0.02	10.0	
Nitrate+Nitrite as N (Calculation)	2.63	mg/L	0.03		
Nitrite as N	<0.01	mg/L	0.01	1.0	
o-Phosphate as P	<0.05	mg/L	0.05		
pH	7.75	pH	0.01		
pH - Saturation (Calculation) †	6.97	pH	0.01		
Silica-Reactive	10.1	mg/L	0.20		
Sulphate	47.5	mg/L	0.5		
Temperature	21.4	C	0.1		

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02	
Total Suspended Solids	3.6	mg/L	0.6		
Turbidity	6.41	NTU	0.05		
Aluminum	<0.002	mg/L	0.002		
Antimony	<0.0001	mg/L	0.0001	0.006	
Arsenic	0.0002	mg/L	0.0001	0.010	
Barium	0.0972	mg/L	0.0001	1.0	
Beryllium	<0.0001	mg/L	0.0001		
Bismuth	<0.0001	mg/L	0.0001		
Boron	0.018	mg/L	0.010	5.0	
Cadmium	<0.0001	mg/L	0.0001	0.005	
Calcium	101	mg/L	0.05		
Chromium	0.0005	mg/L	0.0001	0.05	
Cobalt	<0.0001	mg/L	0.0001		
Copper	0.0014	mg/L	0.0001		
Hardness (Calculation)	391	mg/L	0.3		
Iron	2.02	mg/L	0.003		
Lead	<0.0001	mg/L	0.0001	0.010	
Lithium	0.0030	mg/L	0.0005		
Magnesium	33.8	mg/L	0.05		
Manganese	0.0057	mg/L	0.0001		
Mercury	<0.05	ug/L	0.05	1	
Molybdenum	0.0011	mg/L	0.0001		
Nickel	0.0011	mg/L	0.0001		
Phosphorus Total	<0.010	mg/L	0.010		
Potassium	1.43	mg/L	0.05		
Selenium	0.0002	mg/L	0.0001	0.05	
Silicon	4.69	mg/L	0.01		
Silver	<0.0001	mg/L	0.0001		
Sodium	46.2	mg/L	0.05	20	*
Strontium	0.306	mg/L	0.0005		
Thallium	<0.0003	mg/L	0.0003		
Tin	<0.0001	mg/L	0.0001		
Titanium	0.0004	mg/L	0.0004		
Tungsten	<0.0001	mg/L	0.0001		
Uranium	0.431	ug/L	0.002	20	
Vanadium	<0.0001	mg/L	0.0001		
Zinc	0.013	mg/L	0.001		
Zirconium	<0.0004	mg/L	0.0004		
Escherichia coli	0	MPN/100mL	0	0	
Total Coliform	0	MPN/100mL	0	0	
1,1-Dichloroethylene	<0.2	ug/L	0.2	14	
1,2-Dichlorobenzene	<0.2	ug/L	0.2	200	
1,2-Dichloroethane	<0.2	ug/L	0.2	5	
1,4-Dichlorobenzene	<0.2	ug/L	0.2	5	
Benzene	<0.2	ug/L	0.2	1	
Bromodichloromethane	<0.2	ug/L	0.2		
Bromoform	<0.2	ug/L	0.2		
Carbon Tetrachloride	<0.2	ug/L	0.2	2	
Chlorobenzene	<0.3	ug/L	0.3	80	
Chloroform	<0.2	ug/L	0.2		
Dibromochloromethane	<0.2	ug/L	0.2		
Dichloromethane	<0.5	ug/L	0.5	50	
Ethylbenzene	<0.2	ug/L	0.2	140	
m+p-Xylene	<0.4	ug/L	0.4		
o-Xylene	<0.2	ug/L	0.2		
Tetrachloroethylene	<0.2	ug/L	0.2	10	
Toluene	<0.2	ug/L	0.2	60	

Analyte	Result	Units	MDL	ODWS (Amnd O.Reg.457/16) Jan2020 02
Total Trihalomethanes (Calculation)	<0.4	ug/L	0.4	100
Trichloroethylene	<0.2	ug/L	0.2	5
Vinyl Chloride	<0.2	ug/L	0.2	1
Xylene (Calculation)	<0.5	ug/L	0.5	90

Report Comment: The ODWS does not specify a MAC for sodium, however, as per section 18 of the SDWA, sodium results above 20 mg/L on a regulatory sample are prescribed as adverse results with a duty to report as specified in the applicable regulation.

Client:Silverio/Bourke/Sarwar/City of Hamilton
Project:Carlisle Redundant Well

ISO# 2023282
Location: A4
2 for 18O, 2H

Environmental Isotope Lab
2023-05-12

#	Sample	Date	Lab#	$\delta^{18}O$	Result	Repeat	$\delta^{2}H$	Result	Repeat		pH	SPC	AZD
				H_2O	VSMOW	± 0.2‰	H_2O	VSMOW	± 0.8‰			uS/cm	
1	FDC03RR	04-May-23	505861	X	-10.92	-10.89	X	-69.22	-69.13	100ml	7.25	1040	
2	FDC03R	04-May-23	505862	X	-10.84		X	-68.34		100ml	7.29	932	

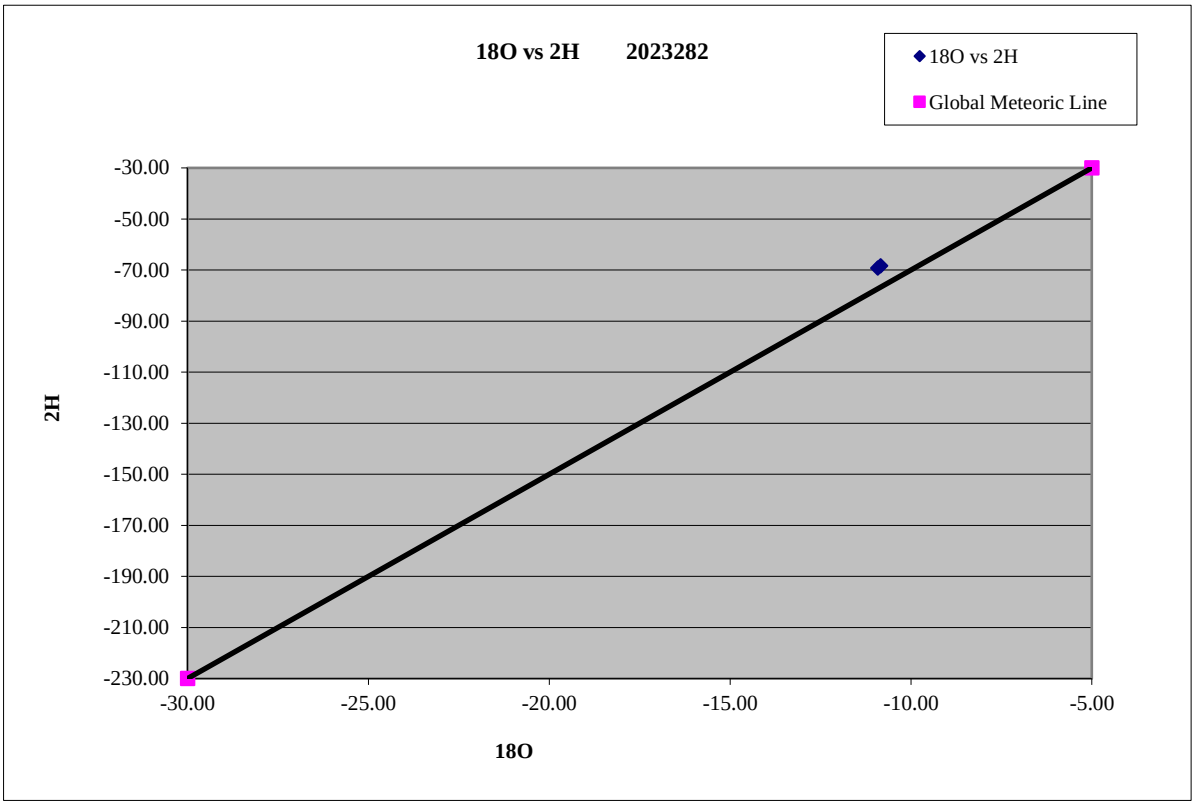
BAL= Below Analytical Limit
NA= Not Attempted (concentrations too low)
NES= Not Enough Sample
ND= Non-detect

ENVIRONMENTAL ISOTOPE LABORATORY

Silverio 2023282

-10.92	-10.89	-69.22	-69.13
-10.84		-68.34	

-5	-30
-30	-230



York-Durham Regional Environmental Laboratory
901 McKay Road
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Phone (905)686-0041 Fax (905)686-0664

LABORATORY ANALYSIS REPORT

Work Order #: 104412 **Work ID:** REL23-2336

Description:
Client: City of Hamilton
Profile: Non-regulated Water Sampling
Sampled By: Frank/Lauren
Sample Count: 4

Report To: Ahmad Sarwar
84 Acredale Drive
Hamilton, ON

Authorized by: Imran Iftakhar, Group Leader

Workorder Summary

Workorder Comments

Cryptosporidium and Giardia Internal Control – Percent Recovery: Cryptosporidium, 70%; Giardia, 71%.

Sample Comments

10441201 (MPA-1) - Ground Water

The bioindicators Giardia, Cryptosporidium, Diatoms, Other Algae, Rotifers, Insect/Larvae and Plant Debris (Chlorophyll containing), were calculated to have a relative risk factor of 0 (not significant). According to the USEPA Consensus method (1992, EPA910/9-92-029) the relative risk score of surface water contamination is 0 – Low Risk.

Volume Filtered value provided by client.

10441203 (MPA-2) - Ground Water

The bioindicators Giardia, Cryptosporidium, Diatoms, Other Algae, Rotifers, Insect/Larvae and Plant Debris (Chlorophyll containing), were calculated to have a relative risk factor of 0 (not significant). According to the USEPA Consensus method (1992, EPA910/9-92-029) the relative risk score of surface water contamination is 0 – Low Risk.

Volume Filtered value provided by client.

Task Comments

10441201 - 4705421 - MBI/73583

Microscopic Particulate Analysis - Parameter results have been adjusted to reflect 100L of the original sample volume.

10441203 - 4705427 - MBI/73583

Microscopic Particulate Analysis - Parameter results have been adjusted to reflect 100L of the original sample volume.

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

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LABORATORY ANALYSIS REPORT

Work Order #: 104412 **Work ID:** REL23-2336

Analytical Results

Lab ID: 10441201 **Sample ID:** MPA-1 **Criteria:** N/A **Date Received:** 5/3/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/2/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
CRYPTOSPORIDIUM / GIARDIA (RELM-9)									
Cryptosporidium oocysts	0	n/a	1	1	1		05/04/2023	05/09/2023	
Filtered Volume	20	L					05/04/2023	05/09/2023	
Giardia cysts	0	n/a	1	1	1		05/04/2023	05/09/2023	
PHYTOPLANKTON (RELM-15)									
Algae >15um	0	n/a		60	1		05/09/2023	05/09/2023	
Algae 2-7um	0	n/a		60	1		05/09/2023	05/09/2023	
Algae 7-15um	0	n/a		60	1		05/09/2023	05/09/2023	
Amoebae	0	n/a		60	1		05/09/2023	05/09/2023	
Crustaceans, Parts	0	n/a		60	1		05/09/2023	05/09/2023	
Diatoms	0	n/a		60	1		05/09/2023	05/09/2023	
Filtered Volume	20	L					05/09/2023	05/09/2023	
Gastrotrichs	0	n/a		60	1		05/09/2023	05/09/2023	
Insects, Parts	0	n/a		60	1		05/09/2023	05/09/2023	
Invertebrate eggs	0	n/a		60	1		05/09/2023	05/09/2023	
Nematodes, eggs	0	n/a		60	1		05/09/2023	05/09/2023	
Pollen	120	n/a		60	1		05/09/2023	05/09/2023	
Protozoa	0	n/a		60	1		05/09/2023	05/09/2023	
Rotifers, eggs	0	n/a		60	1		05/09/2023	05/09/2023	
Spores	0	n/a		60	1		05/09/2023	05/09/2023	
Tardigrades	0	n/a		60	1		05/09/2023	05/09/2023	
Vegetative debris	0	n/a		60	1		05/09/2023	05/09/2023	

Lab ID: 10441202 **Sample ID:** Fcolliphage -1 **Criteria:** N/A **Date Received:** 5/3/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/2/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
COLIPHAGES (RELM-16)									
Male-Spec. Coliphage DNA+RNA	0	PFU/100mL	1	1	1		05/03/2023	05/04/2023	
Male-Spec. Coliphage RNA	0	PFU/100mL	1	1	1		05/03/2023	05/04/2023	

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

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LABORATORY ANALYSIS REPORT

Work Order #: 104412 **Work ID:** REL23-2336

Analytical Results

Lab ID: 10441203 **Sample ID:** MPA-2 **Criteria:** N/A **Date Received:** 5/3/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/3/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
CRYPTOSPORIDIUM / GIARDIA (RELM-9)									
Cryptosporidium oocysts	0	n/a	1	1	1		05/04/2023	05/09/2023	
Filtered Volume	20	L					05/04/2023	05/09/2023	
Giardia cysts	0	n/a	1	1	1		05/04/2023	05/09/2023	
PHYTOPLANKTON (RELM-15)									
Algae >15um	0	n/a		60	1		05/09/2023	05/09/2023	
Algae 2-7um	0	n/a		60	1		05/09/2023	05/09/2023	
Algae 7-15um	0	n/a		60	1		05/09/2023	05/09/2023	
Amoebae	0	n/a		60	1		05/09/2023	05/09/2023	
Crustaceans, Parts	0	n/a		60	1		05/09/2023	05/09/2023	
Diatoms	0	n/a		60	1		05/09/2023	05/09/2023	
Filtered Volume	20	L					05/09/2023	05/09/2023	
Gastrotrichs	0	n/a		60	1		05/09/2023	05/09/2023	
Insects, Parts	0	n/a		60	1		05/09/2023	05/09/2023	
Invertebrate eggs	0	n/a		60	1		05/09/2023	05/09/2023	
Nematodes, eggs	60	n/a		60	1		05/09/2023	05/09/2023	
Pollen	60	n/a		60	1		05/09/2023	05/09/2023	
Protozoa	0	n/a		60	1		05/09/2023	05/09/2023	
Rotifers, eggs	0	n/a		60	1		05/09/2023	05/09/2023	
Spores	0	n/a		60	1		05/09/2023	05/09/2023	
Tardigrades	0	n/a		60	1		05/09/2023	05/09/2023	
Vegetative debris	0	n/a		60	1		05/09/2023	05/09/2023	

Lab ID: 10441204 **Sample ID:** Fcolliphage -2 **Criteria:** N/A **Date Received:** 5/3/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/3/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
COLIPHAGES (RELM-16)									
Male-Spec. Coliphage DNA+RNA	0	PFU/100mL	1	1	1		05/03/2023	05/04/2023	
Male-Spec. Coliphage RNA	0	PFU/100mL	1	1	1		05/03/2023	05/04/2023	

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

York-Durham Regional Environmental Laboratory

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LABORATORY ANALYSIS REPORT

Work Order #: 104412 **Work ID:** REL23-2336

York-Durham
Regional Environmental Laboratory
901 McKay Road, Pickering ON L1W 3A3 Toll Free: 1-877-551-8877 Local: 905-686-0041
Fax: 905-686-0664 Email: rel@durham.ca Web: www.durham.ca

REL23-2336

Non-regulated Water, Wastewater,Biosolid,Soil
Chain of Custody Form

Client Information	Invoice To (leave blank if same as Client)	Report to (email address)
Company Name: City of Hamilton	Company:	1) Ahmad.Sarwar@hamilton.ca
Facility Name: Carlisle Redundant Well		2)
Facility Address: 84 Acredale Drive, Carlisle	Quote #:	3)
Facility Contact: Ahmad Sarwar	PO #:	4)
Email: Ahmad.Sarwar@hamilton.ca Tel: (905) 546-2424 Ext. 1752		5)
Project Information (if applicable) Description:	Standard Turnaround Time (TAT) is 10 business days ☐ *RUSH	*Rush TAT requires lab approval in advance. Surcharge will apply.

Sample(s) Information

Lab ID (lab use only)	Field ID	Location/Description/Comment(s)	Matrix	Type	Collection mm-dd-yy	Collection HH:MM	Test Group(s)	Container Type	Container Sent	Container Rec'd	Chlorine Free	Chlorine Total	Apply Criteria (Y/N) (*1)
01	MPA-1	FDC03RR	Water	Groundwater	05-02-23	10:00	MBCG MPA		1	1			
02	Fcolliphage-1	FDC03RR	Water	Groundwater	05-02-23	12:00	E.coliphage		2	2			
03	MPA-2	FDC03RR	Water	Groundwater	05-03-23	12:00	MBCG MPA		1	1			
04	Fcolliphage-2	FDC03RR	Water	Groundwater	05-03-23	12:00	E.coliphage		2	2			
	MPA-3	FDC03RR	Water	Groundwater	05-04-23				1				
	Fcolliphage-3	FDC03RR	Water	Groundwater	05-04-23				2				
				Shipment	fee		$25.00						

Sampled By: Frank /Lauren Tel: 647-9720433

Relinquished By (Print/Sign): Frank C. Liu / Date/Time:

(1) Select One Applicable Criteria — Provide Municipality / City / Description

- ☐ Sanitary Sewer Use By-law
- ☐ Storm Sewer Use By-law
- ☐ New Water Main
- ☐ Other

LABORATORY USE ONLY

Delivery Method: Courier ☒ Drop Off ☐ YDREL Pickup ☐
Sorted by: Labelled by: RK
Checked by: KT Proofed by: WO #: 104412

104412

Received Date/Time: MAY 3 2023 12:32
Received By: RK
Comments: Sample 1 - 10.6°C
Sample 3 - 11.6°C

REL-COC-NONREG-NOV-2019-REV-1

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

York-Durham Regional Environmental Laboratory
901 McKay Road
Pickering, ON L1W 3A3
Phone (905)686-0041 Fax (905)686-0664

LABORATORY ANALYSIS REPORT

Work Order #: 104461 **Work ID:** REL23-2340

Description:
Client: City of Hamilton
Profile: Non-regulated Water Sampling
Sampled By: Frank/Lauren
Sample Count: 2

Report To: Ahmad Sarwar
84 Acredale Drive
Hamilton, ON

Authorized by: Imran Iftakhar, Group Leader

Workorder Summary

Workorder Comments

Cryptosporidium and Giardia Internal Control – Percent Recovery: Cryptosporidium, 70%; Giardia, 71%.

Sample Comments

10446101 (MPA-3) - Ground Water

The bioindicators Giardia, Cryptosporidium, Diatoms, Other Algae, Rotifers, Insect/Larvae and Plant Debris (Chlorophyll containing), were calculated to have a relative risk factor of 0 (not significant). According to the USEPA Consensus method (1992, EPA910/9-92-029) the relative risk score of surface water contamination is 0 – Low Risk.

Volume Filtered value was provided by the client.

Task Comments

10446101 - 4710495 - MBI/73583

Microscopic Particulate Analysis - Parameter results have been adjusted to reflect 100L of the original sample volume.

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

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LABORATORY ANALYSIS REPORT

Work Order #: 104461 **Work ID:** REL23-2340

Analytical Results

Lab ID: 10446101 **Sample ID:** MPA-3 **Criteria:** N/A **Date Received:** 5/4/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/4/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
CRYPTOSPORIDIUM / GIARDIA (RELM-9)									
Cryptosporidium oocysts	0	n/a	1	1	1		05/05/2023	05/09/2023	
Filtered Volume	20	L					05/05/2023	05/09/2023	
Giardia cysts	0	n/a	1	1	1		05/05/2023	05/09/2023	
PHYTOPLANKTON (RELM-15)									
Algae >15um	0	n/a		60	1		05/10/2023	05/10/2023	
Algae 2-7um	0	n/a		60	1		05/10/2023	05/10/2023	
Algae 7-15um	0	n/a		60	1		05/10/2023	05/10/2023	
Amoebae	0	n/a		60	1		05/10/2023	05/10/2023	
Crustaceans, Parts	0	n/a		60	1		05/10/2023	05/10/2023	
Diatoms	0	n/a		60	1		05/10/2023	05/10/2023	
Filtered Volume	20	L					05/10/2023	05/10/2023	
Gastrotrichs	0	n/a		60	1		05/10/2023	05/10/2023	
Insects, Parts	0	n/a		60	1		05/10/2023	05/10/2023	
Invertebrate eggs	0	n/a		60	1		05/10/2023	05/10/2023	
Nematodes, eggs	60	n/a		60	1		05/10/2023	05/10/2023	
Pollen	240	n/a		60	1		05/10/2023	05/10/2023	
Protozoa	0	n/a		60	1		05/10/2023	05/10/2023	
Rotifers, eggs	0	n/a		60	1		05/10/2023	05/10/2023	
Spores	0	n/a		60	1		05/10/2023	05/10/2023	
Tardigrades	0	n/a		60	1		05/10/2023	05/10/2023	
Vegetative debris	0	n/a		60	1		05/10/2023	05/10/2023	

Lab ID: 10446102 **Sample ID:** Fcolliphage -3 **Criteria:** N/A **Date Received:** 5/4/2023
Matrix: Water **Location:** FDC03RR **Date Collected:** 5/4/2023
Type: Ground Water **Description:**

Parameter	Results	Units	MDL	RDL	DF	Limit	Prepared	Analyzed	C
COLIPHAGES (RELM-16)									
Male-Spec. Coliphage DNA+RNA	0	PFU/100mL	1	1	1		05/05/2023	05/06/2023	
Male-Spec. Coliphage RNA	0	PFU/100mL	1	1	1		05/05/2023	05/06/2023	

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

York-Durham Regional Environmental Laboratory

901 McKay Road
Pickering, ON L1W 3A3
Phone (905)686-0041 Fax (905)686-0664

LABORATORY ANALYSIS REPORT

Work Order #: 104461 **Work ID:** REL23-2340

York-Durham
Regional Environmental Laboratory
901 McKay Road, Pickering ON L1W 3A3 Toll Free: 1-877-551-8877 Local: 905-686-0041
Fax: 905-686-0664 Email: rel@durham.ca Web: www.durham.ca

REL23-2340

Page 1 of

Non-regulated Water, Wastewater,Biosolid,Soil
Chain of Custody Form

Client Information	Invoice To (leave blank if same as Client)	Report to (email address)
Company Name: City of Hamilton	Company:	1) Ahmad.Sarwar@hamilton.ca
Facility Name: Carlisle Redundant Well		2)
Facility Address: 84 Acredale Drive, Carlisle	Quote #:	3)
Facility Contact: Ahmad Sarwar	PO #:	4)
Email: Ahmad.Sarwar@hamilton.ca Tel: (905) 546-2424 Ext. 1752		5)
Project Information (if applicable) Description:	Standard Turnaround Time (TAT) is 10 business days ☐ *RUSH	*Rush TAT requires lab approval in advance. Surcharge will apply.

Sample(s) Information

Lab ID (lab use only)	Field ID	Location/Description/Comment(s)	Matrix	Type	Collection mm-dd-yy	Collection HH:MM	Test Group(s)	Container Type	Container Sent	Container Rec'd	Chlorine Free	Chlorine Total	Apply Criteria (Y/N) (*1)
	MPA-1	FDC03RR	Water	Groundwater	05-02-23				1				
	Fcolliphage-1	FDC03RR	Water	Groundwater	05-02-23				2				
	MPA-2	FDC03RR	Water	Groundwater	05-03-23				1				
	Fcolliphage-2	FDC03RR	Water	Groundwater	05-03-23				2				
01	MPA-3	FDC03RR	Water	Groundwater	05-04-23	11:00am	MBCGMPA		1	1			
02	Fcolliphage-3	FDC03RR	Water	Groundwater	05-04-23	11:00am	MBC PF		2	2			

Sampled By: Frank /Lauren Tel: 647-9720433

Relinquished By (Print/Sign): Frank C. Liu / Date/Time:

(1) Select One Applicable Criteria — Provide Municipality / City / Description

- ☐ Sanitary Sewer Use By-law
- ☐ Storm Sewer Use By-law
- ☐ New Water Main
- ☐ Other

LABORATORY USE ONLY

Delivery Method: Courier ☑ Drop Off ☑ YDREL Pickup ☐
Sorted by: Labelled by:
Checked by: Proofed by: WO #: 104461

104461

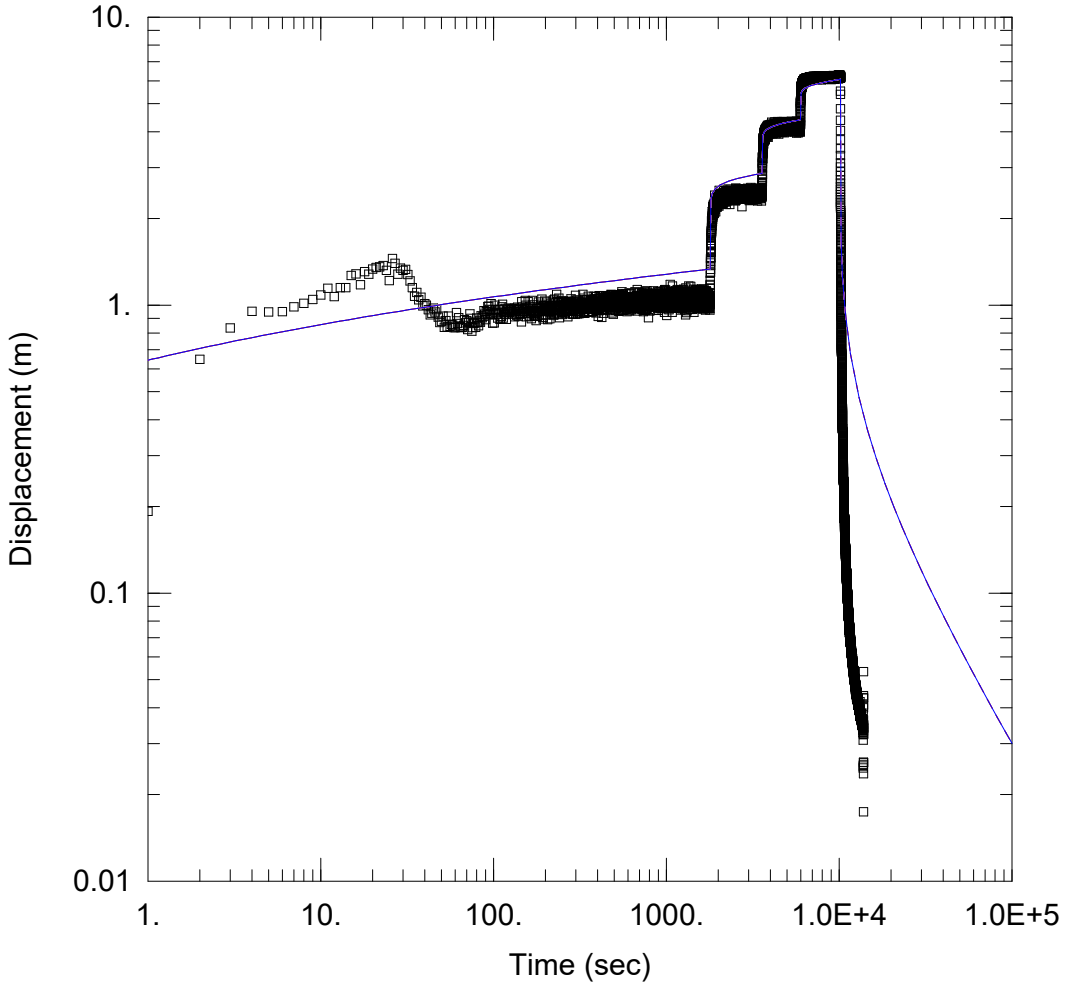
Received Date/Time:
Received By: KF
Comments:
MAY 4 2023 14:05
Received at 12.3°C

REL-COC-NONREG-NOV-2019-REV-1

Legend: MDL = Method Detection Limit; RDL = Reporting Detection Limit; MU = Measurement Uncertainty; < or ND = Less Than or Non-detect; ^ = Result outside limit; Limit = MAC; DF = Dilution Factor; OG = Operational Guideline; AO = Aesthetic Objective; HC = Health Canada; C = Comment; * = Comment Present

Appendix D

Analysis Results of Transmissivity and Storativity



WELL TEST ANALYSIS

Data Set: C:\...\StepTestMay18.aqt
Date: 05/18/23 Time: 09:55:58

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, On
Test Well: FCD03RR
Test Date: April 28, 2023

AQUIFER DATA

Saturated Thickness: 18.5 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FCD03RR	0	0

Observation Wells

Well Name	X (m)	Y (m)
FCD03RR	0	0

SOLUTION

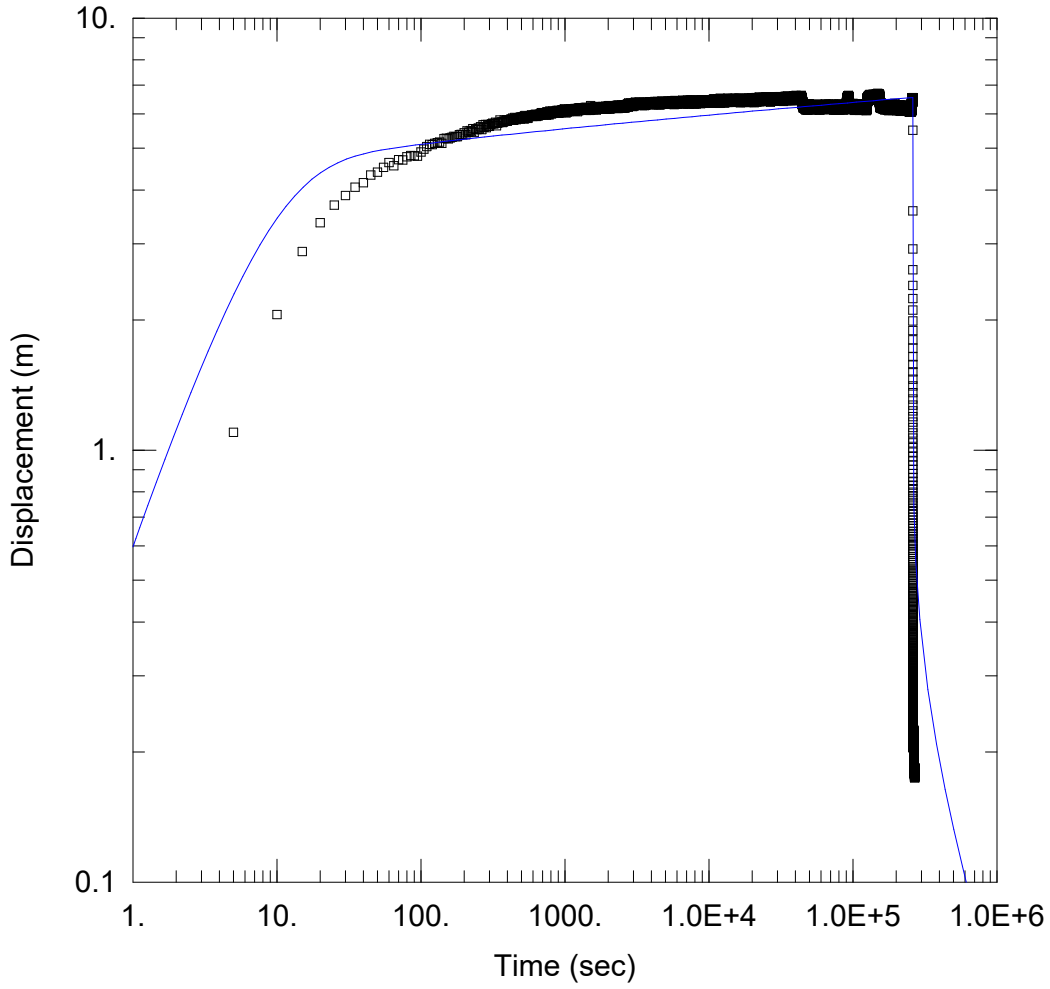
Aquifer Model: Confined
Solution Method: Theis (Step Test)

T = 0.005184 m^2/sec
Sw = 0.
P = 1.5

S = 0.0008802
C = 1. sec^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. sec Rate (Q) in cu. m/sec

$s(t) = 107.1Q + 1.Q^{1.5}$
W.E. = 99.85% (Q from last step)



WELL TEST ANALYSIS

Data Set: G:\...\PumpTest_May_18.aqt
Date: 05/18/23 Time: 09:38:37

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, On
Test Well: FCD03RR
Test Date: May 1-4 2023

AQUIFER DATA

Saturated Thickness: 18.5 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FDC03RR	0	0

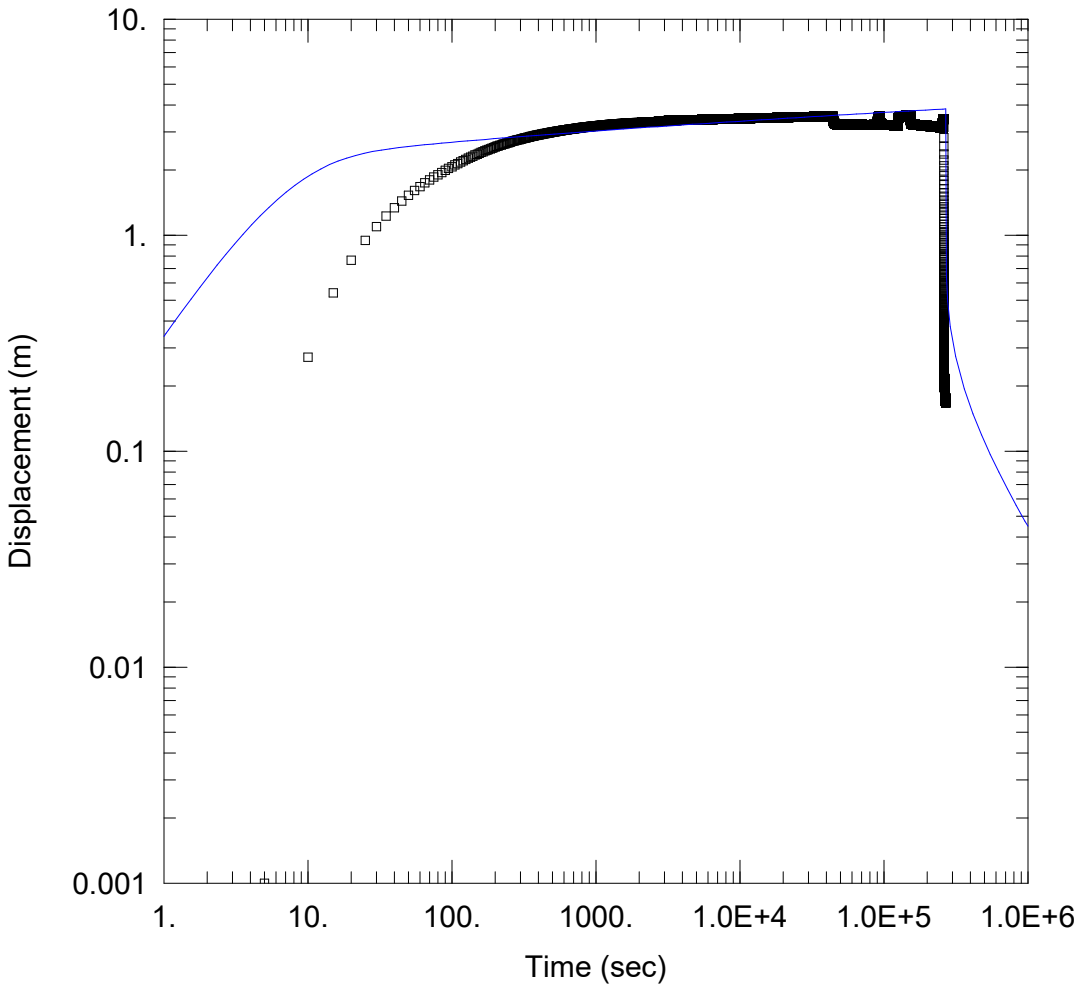
Observation Wells

Well Name	X (m)	Y (m)
□ FDC03RR	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Papadopulos-Cooper

T = 0.01103 m^2/sec S = 8.989E-11
r(w) = 0.111 m r(c) = 0.111 m



WELL TEST ANALYSIS

Data Set: C:\...\PumpTest_FDC03R.aqt
Date: 07/04/23 Time: 07:44:05

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, On
Test Well: FCD03RR
Test Date: May 1-4 2023

AQUIFER DATA

Saturated Thickness: 18.5 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FDC03RR	0	0

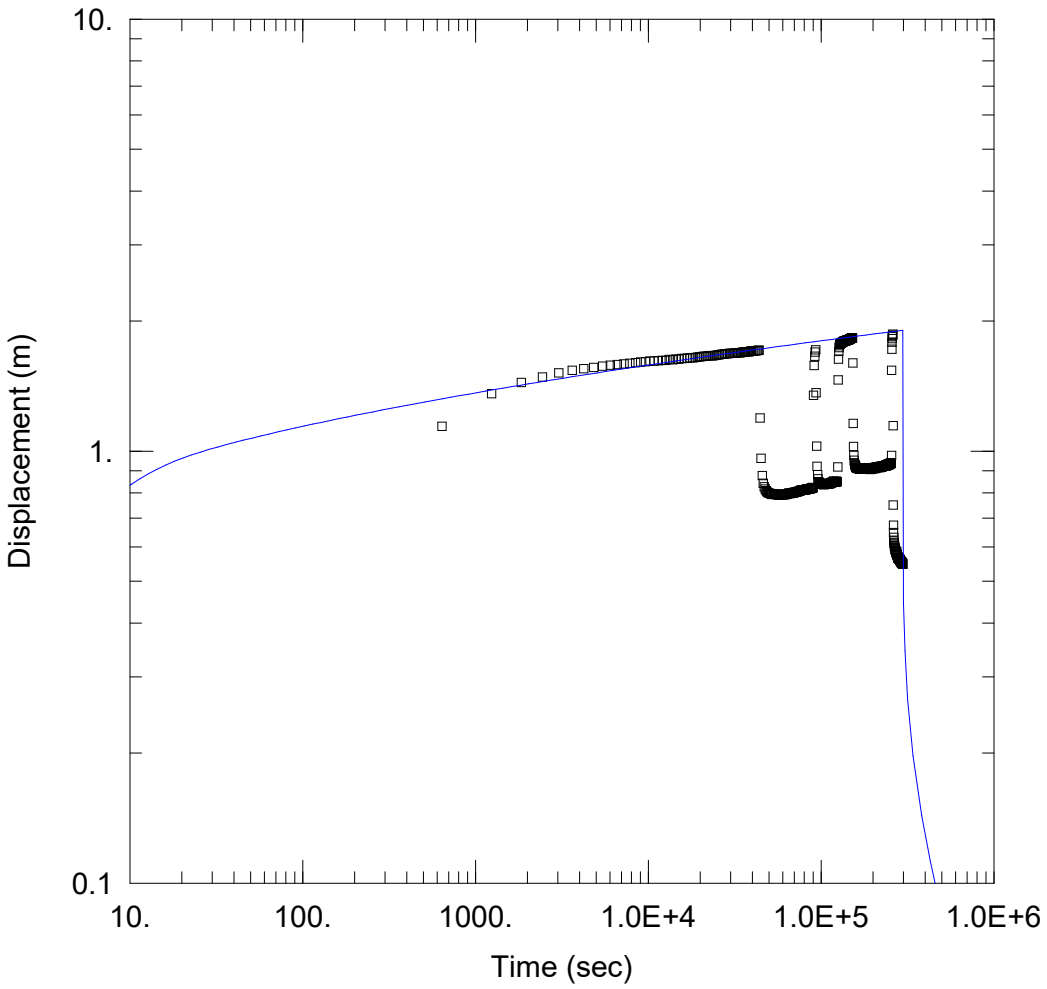
Observation Wells

Well Name	X (m)	Y (m)
FDC03R	14	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper

T = 0.01388 m^2/sec
S = 1.0E-10
r(w) = 0.111 m
r(c) = 0.111 m



WELL TEST ANALYSIS

Data Set: C:\...\PumpTest-CM03-03-D.aqt
Date: 07/04/23 Time: 07:45:35

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, On
Test Well: FCD03RR
Test Date: May 1-4 2023

AQUIFER DATA

Saturated Thickness: 18.5 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FDC03RR	0	0

Observation Wells

Well Name	X (m)	Y (m)
CM-03-03-D	80	0

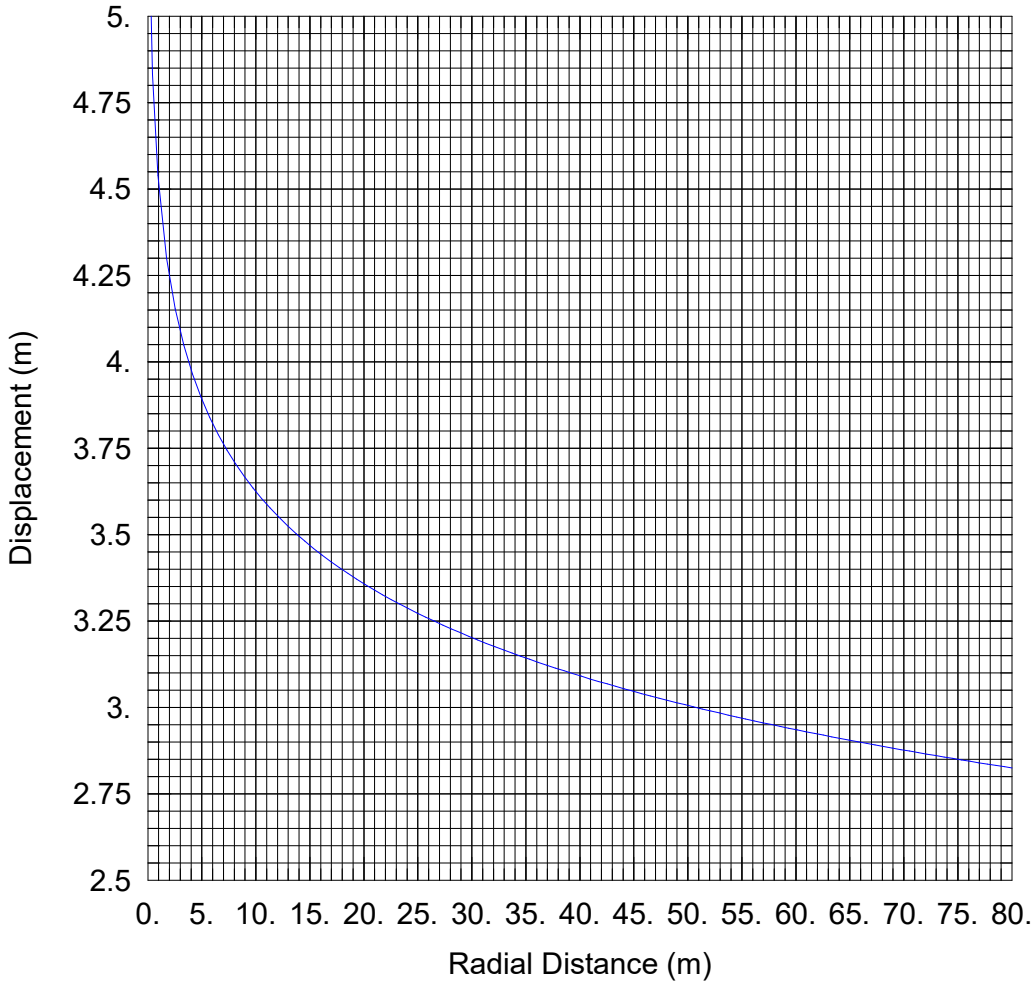
SOLUTION

Aquifer Model: Confined Solution Method: Papadopulos-Cooper

T = 0.02102 m^2/sec S = 4.039E-9
r(w) = 0.111 m r(c) = 0.111 m

Appendix E

Analysis Results of Forward Analysis



WELL TEST ANALYSIS

Data Set: C:\...\Distance-Drawdown.aqt
Date: 06/30/23 Time: 20:48:46

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, ON
Test Well: FDC03RR
Test Date: May1-4, 2023

AQUIFER DATA

Saturated Thickness: 22. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FDC03RR	0	0

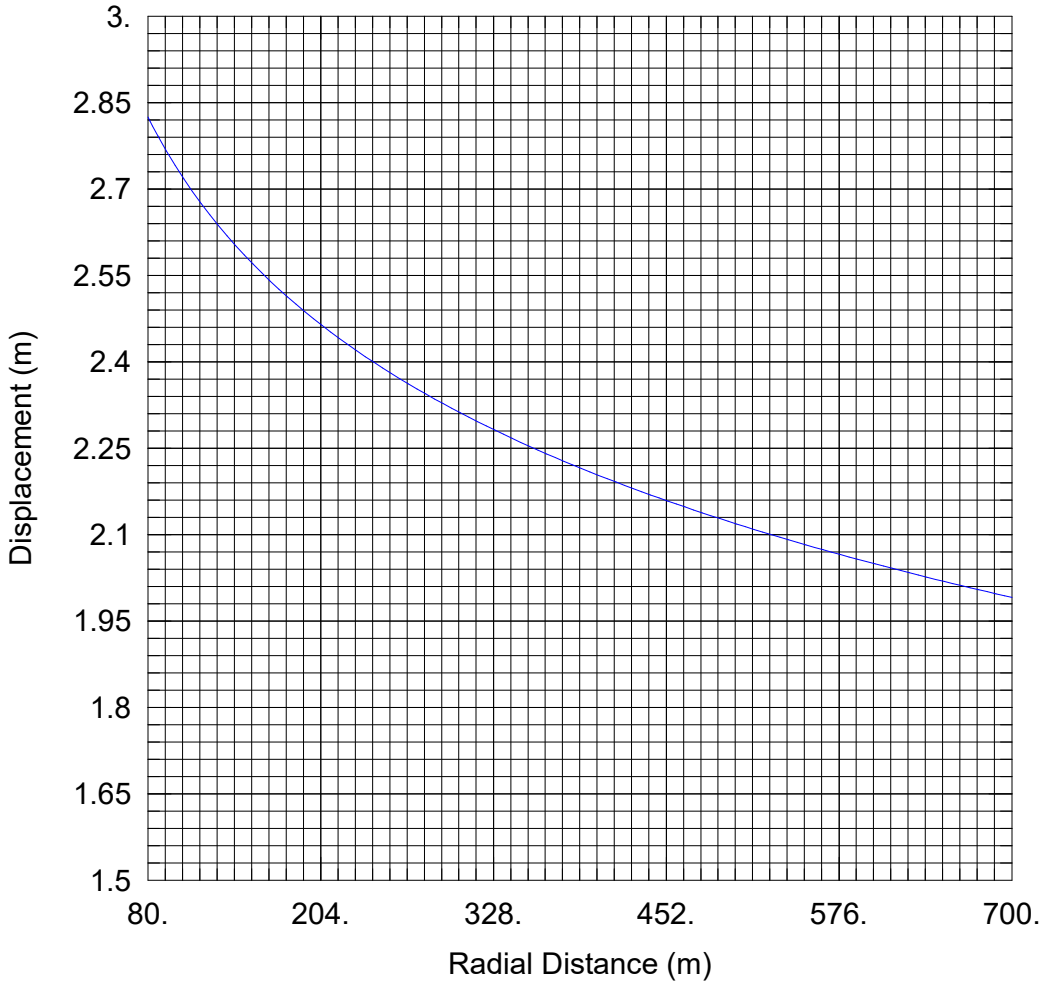
Observation Wells

Well Name	X (m)	Y (m)
▫ FDC03RR	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Papadopulos-Cooper

T = 0.01035 m^2/sec S = 0.00095
r(w) = 0.111 m r(c) = 0.111 m



WELL TEST ANALYSIS

Data Set: C:\...\Forward Analysis.aqt
Date: 06/30/23 Time: 20:56:46

PROJECT INFORMATION

Company: Palmer
Client: RV Anderson Associates
Project: 2108704
Location: Carlisle, ON
Test Well: FDC03RR
Test Date: May1-4, 2023

AQUIFER DATA

Saturated Thickness: 22. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
FDC03RR	0	0

Observation Wells

Well Name	X (m)	Y (m)
▫ FDC03RR	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Papadopulos-Cooper

T = 0.01035 m^2/sec S = 0.00095
r(w) = 0.111 m r(c) = 0.111 m